STEAM AND
HOT WATER HEATING

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CONTENTS

PREFACE

The object of the following pages is to furnish the student with an elementary knowledge of the principles of steam and hot-water heating, together with their application to the practical design of complete systems.

The book is not intended to take the place of more complete works along this line, but to create in the student's mind an interest in the subject, which will lead him to continue his studies by the use of other books which are more advanced. Although in elementary form, the data presented is suitable for use in the design of actual plans, which should add greatly to the student's interest in his work.

The general method employed in presenting the subject has been to give definite rules, applicable to certain conditions most commonly met with in practice.

After these have been thoroughly mastered the changes necessary to meet other and less usual requirements can be taken up, one at a time, by reference to other books, and by a careful study of the current literature along this line in the technical magazines.

This method has seemed to be less confusing than where a number of rules are given covering a variety of conditions. While intended primarily for students just beginning the study of steam and hot-water heating, it will also be found convenient as a book of reference for those already engaged in this line of work.

STEAM AND HOT-WATER HEATING

CHAPTER I

Physics of Heating

Before taking up the actual design of heating systems it is necessary to become thoroughly familiar with certain natural laws which enter into this class of work, and also to obtain a clear understanding of the various terms used.

Heat Unit. The quantity of heat which a body or substance contains is measured in heat units, and is commonly expressed by the abbreviation *TU*.

A heat unit may be defined as the quantity of heat required to raise the temperature of 1 pound of water 1 degree.

EXAMPLES:

(1) How many *TU* are required to raise the temperature of 10 pounds of water 20 degrees?

SOLUTION.—$10 \times 20 = 200$ *TU*.

(2) If a gallon of water weights 8.3 pounds, how many *TU* will be required to raise the temperature of 100 gallons from 60 degrees to 120 degrees?

SOLUTION.—Weight of water, $100 \times 8.3 = 830$ pounds. Degrees rise in temperature, $120 - 60 = 60$. Heat required, $830 \times 60 = 49{,}800$ *TU*.

(3) If 20 gallons of water at a temperature of 200 degrees are mixed with 50 gallons at a temperature of 80 degrees, what will be the temperature of the resulting mixture?

SOLUTION.—In considering the quantity of heat which a volume of water contains at any given temperature, it is customary to start at the point at which ice melts into water, that is, 32 degrees above

zero, so that a pound of water at a temperature of 50 degrees is said to contain $50 - 32 = 18$ *TU* above 32 degrees.

In the present case the first volume of water contains $(20 \times 8.3) \times (200 - 32) = 27{,}888$ *TU*, and the second volume $(50 \times 8.3) \times (80 - 32) = 19{,}920$ *TU*. When the two volumes are mixed we have $(20 + 50) \times 8.3 = 581$ pounds of water, containing $27{,}888 + 19{,}920 = 47{,}808$ *TU* above 32 degrees.

If 1 *TU* will raise the temperature of 1 pound of water 1 degree, then 47,808 *TU* will raise the temperature of 581 pounds of water $47{,}808 \div 581 = 82$ degrees. Hence, the temperature of the resulting mixture will be $32 + 82 = 114$ degrees.

Steam. Steam is the vapor formed when water is heated above a certain temperature under given conditions. When used for heating, the steam is generated in a boiler and conveyed to the radiators through pipes. It has been found by experiment that there is always a definite relation between the pressure and temperature of the steam in a boiler, the latter increasing as the pressure rises. After water begins to boil and steam is generated, there will be no increase in the temperature as long as a constant pressure is maintained, all of the heat passing from the furnace to the water being used in the process of changing it into steam. The heat which disappears in this manner is called *latent heat,* or sometimes latent heat of evaporation, and is given out again when the steam is condensed into water.

The heat required to raise the water from 32 degrees to the boiling point is called the *heat in liquid,* and this, plus the latent heat, the *total heat.* Most problems in steam heating deal with latent heat only.

The point at which boiling or evaporation takes place is fixed by the pressure; this when open to the atmosphere is at 212 degrees.

Table I gives the temperature and latent heat of steam at different pressures, and will be found useful for reference in solving the examples following. More complete tables may be found in almost any Engineers' Handbook, but the quantities most frequently used in heating work are included in Table I.

TABLE I

Gauge pressure, pounds per sq. inch	Temperature degrees F.	Latent heat T. U.	Gauge pressure pounds per sq. inch	Temperature degrees F.	Latent heat T. U.
0	212	966	22	263	930
1	216	963	24	266	928
2	219	961	26	269	926
3	222	959	28	272	924
4	225	957	30	274	922
5	228	955	32	277	920
6	231	953	34	280	918
7	233	951	36	282	916
8	235	950	38	285	915
9	238	948	40	287	913
10	240	946	42	289	911
12	244	943	44	291	910
14	248	940	46	294	908
16	252	938	48	296	907
18	256	935	50	298	905
20	259	933	52	300	904

It will be noted in Table I that the first column is marked *gauge pressure*. This means pressure above the atmosphere. We are surrounded at all times by an atmospheric pressure of approximately 15 pounds per square inch, and the absolute or actual pressure in a steam boiler is 15 pounds more than indicated by the gauge. This is because the type gauge commonly used is so constructed that it indicates differences in pressure between its interior and exterior; hence 15 pounds must be added to gauge readings to obtain absolute pressures. In heating work gauge pressures are commonly employed, and will be used throughout this book, unless otherwise noted. In the case of vacuum heating, so called, where pressures below the atmosphere are made use of, it is customary to express them in *inches of mercury* or *inches of vacuum;* and vacuum gauges are usually made to read in this way. Table II gives the relation between inches of vacuum and pounds pressure per square inch below the atmosphere. The absolute pressure above a total vacuum may be obtained by subtracting the numbers in columns two and four from 15.

TABLE II

Inches of vacuum	Pounds pressure per sq. inch below atmospheric pressure	Inches of vacuum	Pounds pressure per sq. inch below atmospheric pressure
2	.98	16	7.84
4	1.96	18	8.82
6	2.94	20	9.80
8	3.92	22	10.78
10	4.90	24	11.76
12	5.88	26	12.74
14	6.86	28	13.72

The figures in Table I giving the latent heat at different pressures represent the *T U* required to evaporate 1 pound of water into steam at the same temperature, or, putting it the other way, the *T U* given out when 1 pound of steam is condensed into water at the same temperature.

EXAMPLES:

(4) How many *TU* will be required to raise the temperature of 200 pounds of water from 32 degrees and evaporate it into steam at atmospheric pressure?

SOLUTION.—Heat in liquid equals $(212 - 32) \times 200 = 36{,}000$ *TU*. Latent heat equals $200 \times 966 = 193{,}200$ *TU*.

Total, $36{,}000 + 193{,}200 = 229{,}200$ *TU*.

(5) What weight of steam at 10 pounds pressure will it be necessary to condense to raise the temperature of 100 gallons of water 150 degrees?

SOLUTION.—100 gallons of water weighs $100 \times 8.3 = 830$ pounds, and to raise its temperature 150 degrees requires $830 \times 150 = 124{,}500$ *TU*.

The latent heat of steam at 10 pounds pressure is 946. Hence, it will be necessary to condense $124{,}500 \div 946 = 132$ pounds of steam to give the required amount of heat.

(6) A radiator containing 200 square feet of heating surface condenses 0.3 pound of steam per square foot of surface per hour. How many *TU* will be given out per hour with steam at 1 pound pres-

sure? If steam at 20 pounds pressure was used, how many pounds would have to be condensed to give out the same amount of heat?

SOLUTION.—The weight of steam condensed per hour is $200 \times 0.3 = 60$ pounds.

The latent heat of steam at 1 pound pressure is 966. Hence, the heat given out is $60 \times 966 = 57{,}960$ *TU*. With steam at 20 pounds pressure, the latent heat is 933. Therefore, it would be necessary to condense $57{,}960 \div 933 = 62.1$ pounds per hour to obtain the same amount of heat.

(7) A vacuum gauge indicates 10 inches of vacuum in a heating system. What is the absolute pressure in pounds per square inch?

SOLUTION.—From Table II we find that 10 inches of vacuum means that the pressure is 4.9 pounds per square inch less than that of the atmosphere. Subtracting this from 15 (the atmospheric pressure), we find the absolute pressure to be $15 - 4.9 = 10.1$ pounds.

Conduction. The transfer of heat from one body to another, with which it is in contact, or from one part of a body to another, is called conduction. The passage of heat through a pane of window glass or through the metal shell of a steam-pipe are illustrations of this. Some substances conduct heat much more rapidly than others, metals, for example, being good conductors, while wood, cork, and air are poor conductors.

Iron, brass, and copper are used where a rapid transfer of heat is required, as in the case of boilers, radiators, and steam coils. Conduction is retarded by using double glazed windows with an air space between the panes of glass, also by covering steam-pipes with cork or some other substance so made up as to contain a large number of small air cells.

Convection. The currents set up within a body of liquid or gas by unequal temperatures in different parts are called *convection* currents. As a liquid or gas is heated it expands and becomes lighter, hence, has a tendency to rise, while cooler portions flow into take its place. This is illustrated by the hot water rising to the top of a kettle when placed on the fire, and by the flow of hot air and gases up the flue of a chimney. This plays an important part in the circulation of water over the heating surfaces of a steam boiler.

Radiation. Heat flowing through a substance by conduction is passed on by heating the particles of the conducting medium which

are in contact with each other. *Radiant* heat passes through the air without heating it, and is transmitted by a rapid vibration of the surrounding ether. The heat given off from a fireplace is a good illustration of radiant heat.

Temperature. The intensity of heat is called temperature. This, however, does not measure the quantity of heat which a body may contain. Two bodies are said to have the same temperature when no heat will pass from one to the other if placed in contact. Temperature is indicated in degrees by a thermometer, the Fahrenheit scale (F.) being in common use in this country. In this scale the temperature of melting ice is taken as 32 degrees above zero, and the distance which the mercury (or other liquid contained in the bulb) rises when placed in steam at atmospheric pressure is divided into 180 degrees (°). This makes the temperature at which water boils, when open to the atmosphere, $32 + 180 = 212$ degrees.

In the Centigrade scale (C.) the freezing point is marked zero, and the boiling point 100. This scale is hardly ever used in heating work, and the Fahrenheit scale is understood, unless otherwise noted.

To change a Fahrenheit reading to a Centigrade reading, subtract 32 and multiply by 0.55. To change a Centigrade reading to a Fahrenheit reading, multiply by 1.8 and add 32.

Gravity. The force which tends to draw all matter toward the earth is called *gravity*. The term is used in heating to designate those systems where air, steam or water flows through the ducts and pipes without the use of mechanical means.

For example, a "gravity return" is where the water of condensation flows back to the boiler simply because it is at a lower level, and the return pipes are graded toward it. A "gravity system" of warm air heating is where the heated air passes up the flues and into the rooms without the use of fans.

At first thought it is difficult to understand how the force of gravity can cause warm air to rise through a flue or hot water to pass upward from a boiler to the radiators above. This may be easily explained by reference to Figs. 1 and 2. In Fig. 1 let *A B C* be a tube bent in the form of a **U**. Let the leg *A* be partly filled with water, and *B* with mercury to the same level. *C* is a stationary diaphragm holding them apart. If now the diaphragm is removed the mercury, being heavier than water, will fall in tube *B* and rise in *A* until it stands at the same in both. When the mercury flows into *A* it, of course,

forces the column of water upward; hence, we see how the force of gravity may cause a body to rise under certain conditions. The water rises because it is forced upward by a heavier liquid flowing in below it. The force of gravity is tending to pull both the water and the mercury toward the earth, but acts with a greater force on the mercury, with the result described. If the mercury were replaced by

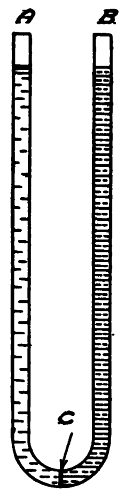


FIG. 1

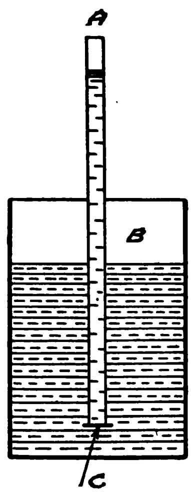


FIG. 2

water at a lower temperature than in *A*, the result would be the same, although it would take place more slowly, owing to the smaller difference in weight between the two columns.

This principle is made use of in hot water heating by connecting the bottom of tube *A* with a furnace, which always keeps the water hotter, and therefore lighter, than in tube *B*, which is connected with the return from the radiators. By maintaining a difference in temperature between the two columns a circulation may be kept up indefinitely.

The flow of warm air through a flue is best explained by reference to Fig. 2. Here the **U** tube is replaced by a straight tube *A*, partly filled with water and closed at the bottom with a diaphragm *C*, as before. *B* is a vessel containing mercury. If, now, the diaphragm *C* be removed, mercury will flow into the bottom of tube *A* until it reaches the level of that in the vessel, forcing the water in the tube upward, as in the previous illustration. If, now, the tube *A* be re-

placed by a flue filled with warm air, and the surrounding atmosphere at a lower temperature takes the place of the mercury, the general result will be the same. As long as warm air is supplied at the bottom of the flue, the cooler, and therefore heavier, air of the surrounding atmosphere will tend to force it upward.

TEST QUESTIONS:

(1) What is a heat unit, and what symbol is used to express it?

(2) When steam is generated at a constant pressure, does the temperature of the water rise as more heat is applied?

(3) What is latent heat? What is heat in liquid? What is total heat?

(4) Define conduction. Name a good conductor and a poor conductor.

(5) Give an illustration of convection, and state the reason for convection currents.

(6) Is the air of a room warmed by the radiant heat from a fireplace?

(7) Does the temperature of a body indicate the quantity of heat which it contains? What is the zero of the Centigrade scale? Of the Fahrenheit scale? How may Fahrenheit readings be changed to Centigrade?

(8) What is gravity?

(9) What causes the water from a hot water heating boiler to flow upward to the radiators?

(10) Explain why the warm air in a flue rises.

CHAPTER II

Systems of Heating

The methods of heating in common use may be divided into three general classes:

First, where the source of heat is placed directly in the room to be warmed, as in the case of a stove or fireplace;

Second, where the heat is generated at a distance and transmitted in the form of hot air, to be mixed directly with the air of the rooms;

Third, where the heat is generated at a distance and transmitted in the form of steam or hot water, to be condensed or cooled in radiators, and thus give up a portion of its heat to the rooms by conduction and radiation.

In practice, these three general methods of heating are subdivided and combined into a large number, embodying a great variety of arrangements and different devices, the more important of which will now be described in some detail.

Fireplaces. The fireplace is the oldest form of heating employed for the warming of dwellings. It is used extensively at the present time in the better class of houses as supplementary to some other general system of heating. Its use is usually confined to the warming of certain rooms on cool mornings or evenings in spring and fall, when the regular system of heating is closed down for the summer, or on especially cold days in the winter when additional heat is needed. In other cases it is used simply for the pleasure which an open fire affords or for purposes of ventilation.

Stoves. Stoves followed the fireplace, and are still extensively used in the country and in the poorer class of town and city houses. This is the cheapest system of heating to install, and in the average dwelling of small size the most economical to operate. Stoves are, however, the cause of more or less dust and litter in the rooms, and require considerable attention in order to produce an even temperature.

Hot-Air Furnaces. This method of heating is very extensively employed in nearly all classes of dwellings except the largest, and follows the stove in first cost. A furnace is simply a large stove of

special construction, furnished with a brick or sheet-iron casing so arranged as to provide an air space between it and the heating surfaces of the stove. The lower part of this space is connected with the outer air by means of a duct, commonly called the "cold-air box," while from the top of the casing sheet-metal pipes or flues lead to the various rooms for conveying the warm air.

The operation is simple and easily explained by the principles described in the previous chapter. The air in the space inside the furnace casing becomes heated through contact with the hot surfaces, and, therefore, being lighter than the surrounding atmosphere, is forced upward through the flues by the cooler outside air flowing in through the cold-air box. As this operation is continuous, so long as a fire is maintained in the furnace, it is evident that this system furnishes a constant supply of fresh air to the various rooms as well as heating them. This is an important point in favor of this method of heating, although it increases the amount of fuel burned and so adds to the cost of operation.

A furnace is much more convenient to care for than a number of stoves. Being located in the cellar, the labor involved in handling the coal and ashes is much less, and the litter which accompanies the use of stoves is considerably reduced.

The body of fire carried, being larger, is more easily regulated to meet the requirements, hence a more even temperature may be maintained throughout the house. To give the best results the furnace should be of ample size, the ducts both for cold and warm air free from sharp bends or other obstructions to the easy flow of air.

The cold-air box is frequently made of matched sheathing, although galvanized iron is better, as it admits of a tighter construction and has a smooth interior surface. The warm-air pipes and flues are usually of heavy tin or of light galvanized iron for the larger sizes. Dampers are placed in all ducts and pipes for regulating the air flow under different conditions. The warm air is brought into the rooms through registers of metal grille work, placed either in the floor or in the wall near the baseboard.

As this system of heating is dependent upon a constant flow of warm air into the rooms it is evident that there must be some means provided for the escape of the cooler air to make room for it.

This is cared for partly by leakage around doors and windows,

partly by fireplaces, and partly by special vent-flues provided for the purpose.

Furnaces are adapted to the warming of dwelling houses, and small stores, churches, halls, and schoolhouses.

Steam Heating. This method of heating, in various forms, is probably more widely used than any other system. It is adapted to almost any type of building, and heat can be carried long distances from the point where it is generated without serious loss.

Direct Steam. The simplest form of steam heating is known as the *direct* system. This consists of a boiler for generating the steam, commonly placed in the cellar or basement; a system of pipes for carrying the steam to the rooms and for returning the condensation to the boiler; and radiators in the rooms for condensing the steam and liberating the heat which it contains.

The only essential difference in principle between direct steam and a hot-air furnace is that the carrying medium for the heat is steam instead of air. The grate and fire pot for burning the coal are practically the same in each case, but instead of warming a large volume of air to be carried to the room through a flue of comparatively large size, the heat is stored in the steam, in the form of latent heat, and then transmitted through a small pipe to the radiator. A room requiring an air flue 10 or 12 inches in diameter may be easily warmed by the steam flowing through a 1-inch pipe. A *radiator* is a metal chamber of such form as to have a large amount exposed external surface compared with its volume. They are sometimes made up of a large number of wrought-iron pipes, and sometimes of cast-iron slabs or sections of various forms joined together. When filled with steam the heat is conducted through the walls of the radiator to the surrounding atmosphere, which is at a lower temperature. As this heat is given out, the steam is condensed again into water, which flows back to the boiler through pipes provided for this purpose. Here it is again changed into steam and the process repeated. The same water is used over and over again, only enough being added from time to time to replace any small amount which may be lost through leaks at the joints or valves. An important matter in connection with steam heating is the removal of air from the pipes and radiators. As steam from the boiler flows into the pipes the air is forced back, and being heavier than steam, settles in the lowest parts of the system, and if not drawn off will prevent

the steam from entering. This results in a poor circulation through the pipes and causes portions of the radiators to remain cold and therefore useless for heating purposes. This condition is overcome by placing *air-valves* in the lower part of the radiators at the opposite end from which the steam enters. When steam is first turned on the air valve is opened and the air expelled, after which the radiator remains steam filled until it is either shut off or the pressure drops and air again finds its way in.

Among the advantages of direct steam are its simplicity, and the ability to heat all rooms alike regardless of their location or the direction of the wind, which is sometimes difficult, if not impossible, with a hot-air furnace. Steam is raised quickly in the morning, and when a radiator is shut off the small amount of condensation remaining is too small to cause damage by freezing.

The two principal disadvantages of this system are that it does not provide any fresh air for ventilating purposes, and there is no simple way of regulating the amount of heat given off, except by shutting off and turning on the radiators. This applies, however, more especially to the system just described, where a steam pressure somewhat greater than that of the atmosphere is carried in the radiators; this pressure, in ordinary low-pressure heating, commonly ranging from 1 to 5 pounds per square inch.

Vacuum Systems. In order to overcome, to some extent, the difficulty above mentioned, and obtain a certain amount of temperature regulation, *vacuum* systems, so called, are often employed. These are included in two general classes, although the principle involved is the same in each. We have learned in the previous chapter that the temperature of steam varies with the pressure; for example, steam at 1 pound absolute pressure, which is approximately 28 inches of vacuum, has a temperature of 102 degrees, while at atmospheric pressure it is 212 degrees. As the amount of heat given off by a radiator varies with the difference in temperature between the steam which fills it and the surrounding air, it is evident that a variation in the steam pressure, and the resulting change in temperature, will vary the amount of heat given off by the radiator. This is the fundamental principle upon which vacuum systems operate.

In the arrangement commonly used for dwelling houses, the radiators are provided with air valves so constructed that they will open and allow the air to flow out when the steam pressure exceeds

that of the atmosphere, but will not allow it to enter again when the pressure drops below that point. In operation, the steam pressure is raised slightly above that of the atmosphere and the air forced out of the system, then the fire is slacked, and the pressure allowed to drop to such a point that the temperature of the steam is just sufficient to give off the required amount of heat. The amount of regulation is limited with this system, as it is difficult to maintain a low pressure in the radiators and piping, for any great length of time, owing to the tendency of air to leak in at the joints and around valve stems. In the other arrangement a vacuum pump is attached to the main return from the system, and a high vacuum maintained in the return piping. A special automatic valve is connected to the return end of each radiator, being so constructed that it will allow the water of condensation to be drawn out, but will not permit the passage of steam. Steam is supplied to the radiator through a regulating valve in quantities just sufficient to furnish the desired amount of heat. Direct steam is adapted to nearly all classes of buildings except where ventilation is required, and in cases where the appearance of direct radiators in the rooms is objectionable.

Indirect Steam. This system of heating combines the advantages of both direct steam and hot air, where ventilation is desired. The radiators in this case are of a special form and commonly hung just below the basement ceiling. They are provided with galvanized-iron casings and connected with the outside air and the rooms above by means of ducts and flues.

The arrangement is similar to a hot-air furnace except a steam radiator takes the place of a stove for heating the air. The advantage of this system over the furnace is that a separate radiator, or *stack,* as it is called, may be placed at the base of each flue, or group of flues, thus doing away with long runs of horizontal piping which are necessary to connect a furnace with the different uptake flues. When the source of heat is placed directly at the base of the flue, the air flow is likely to be much more steady and less liable to be affected by winds and other outside weather conditions. Again, in many buildings, it is desirable to supply fresh air to a portion of the rooms, while others require heat only. In such cases a combination of direct and indirect steam makes an ideal arrangement.

The temperature of the air entering the rooms is usually regulated by a special damper arrangement, which varies the proportions of the

hot and cold air making up the mixture supplied to the rooms. The boiler and the general method of running the piping is practically the same as for direct-steam heating, while the air flues correspond to those used in furnace heating. Indirect steam is adapted to dwelling houses of large size, schools, churches, and halls, or wherever air is required for ventilation.

Exhaust Steam Heating. This method of heating does not vary from any other, except that exhaust steam from the engines and pumps of a power plant is used instead of live steam directly from the boilers. The system of piping and radiators is practically the same as already described for direct and indirect heating.

The only special apparatus required are devices for removing the oil from the steam and traps and pumps for returning the water of condensation to the boilers against a higher pressure. The action of these will be described in a later chapter.

Hot Water Heating. A system of hot water heating is similar in operation to those just described, except hot water flows through the pipes and radiators instead of steam.

The boilers used are practically the same, except there is no steam space provided, the whole system, including boiler, pipes, and radiators, being filled with water. The only additional equipment required is an *expansion* tank. Water, when heated, expands a given amount, depending upon its temperature, hence some provision must be made for catching the overflow when the temperature is raised, and for returning it again when lowered. This is accomplished by placing a vented tank above the highest radiator, and carrying a pipe from some convenient part of the system into the bottom of it. As the water expands, the surplus overflows into the tank, and flows out again when contraction takes place, due to cooling. Radiators for hot water heating are somewhat different in their interior construction than for steam, although their exterior appearance is much the same. A system designed for hot water can always be used for steam, so far as the radiators and piping are concerned, but all steam systems cannot be used for hot water, as will be explained later.

Provision must be made for air venting the same as for steam, although this can be made practically automatic by a proper arrangement of the piping.

The heat carried from the boiler to the radiators in this case is not

latent heat, but is simply stored in the water, and is given out as the water cools in slowly passing through the radiators. The circulation through the system is produced solely by the difference in temperature and weight of the water in the supply risers and in the return drops. After being cooled in the radiators it flows back to the boiler, where it is reheated and again makes the circuit, the operation being continuous.

Hot water is adapted to both the direct and indirect systems, and may be used in practically the same manner as steam.

Temperature regulation in the rooms is easily secured by varying the temperature of the water circulated through the system, and this in turn is regulated by the amount of fire carried, the same as in furnace heating. For this reason, it is especially adapted to the warming of dwelling houses and similar buildings. A system of hot-water heating is more expensive to instal than one for steam, as the radiators are necessarily somewhat larger, owing to their lower temperature under ordinary conditions.

Among the objections commonly raised against hot water is the danger of freezing when a radiator is shut off in very cold weather, and the length of time required to warm up a building in the morning, owing to the large body of water to be heated.

As the force producing the circulation is very slight in case of gravity, or natural circulation due to differences of temperature, it is not adapted to large buildings, unless some mechanical means are provided for forcing the water through the mains.

Centrifugal or rotary pumps are commonly used for this purpose, driven either by a steam engine or electric motor. This system of heating is frequently used in connection with a power plant, the exhaust steam from the engines being used for warming the water in heaters especially designed for this purpose. This system is extensively used in office buildings, factories, and schools.

Hot-Blast Heating. In this system of heating the air is usually warmed by passing through large heaters or *blast coils* filled with steam, but is forced through the ducts and flues by means of a fan instead of flowing by gravity, as in the ordinary indirect method. This system is adapted to buildings where large volumes of fresh air are to be supplied continuously, as in schools, churches, halls, theatres, etc.

It is often used in connection with a direct heating system for

ventilating purposes only. That is, the air is delivered to the building at the normal temperature of the rooms (about 70 degrees), and the heat for warming is furnished by an independent system of direct radiation. In other cases it is combined with a system of indirect heating. A large main or *primary* heater, so called, being used to warm the air up to 70 degrees, while indirect stacks are placed at the bases of the flues leading to the individual rooms, to furnish the additional heat required for warming. In the *double-duct* system the air is first passed through a heater which raises its temperature to about 60 degrees. Then a portion is passed through a second heater which raises it to a temperature considerably higher. A system of double ducts is provided, running side by side, one carrying cool or tempered air, and the other hot air. At the bases of the flues leading to the rooms, air from these two ducts is mixed in the right proportion to give the desired temperature to the rooms.

Hot-blast heating is especially adapted to the warming of shops and factories, and is extensively employed for this purpose. As the cubic space in these buildings is often large compared with the number of occupants, *rotation* heating is commonly resorted to for a part of the time. With this method a part, or the whole, of the air passed through the fan and heater is taken from the interior of the building, instead of from out of doors. That is, the same air is circulated through the building over and over again in much the same way as the water in a hot water heating system, the air in this case being simply a medium for transferring the heat from the steam coils to different parts of the building.

In arrangements of this kind, provision is made for taking sufficient fresh air from the outside to maintain a proper standard of purity in the building. This amount will vary under different local conditions, and must be determined in each particular case.

Although steam is commonly used in hot-blast coils, hot water may be employed, if more convenient, provided the heating coils are especially designated for this purpose.

Electric Heating. This method of heating is not employed to any great extent at the present time, owing to the excessive cost as compared with other systems. It is very convenient, however, for warming small rooms which are difficult to reach with pipes or flues, and for heating bathrooms, dens, etc., on cold mornings, when the regular system of heating is not in use.

As the current is easily turned on and off, heat is supplied only as needed, hence the expense is not so great as if operated under conditions similar to other systems.

TEST QUESTIONS:

(1) Into what three classes may heating systems be divided?

(2) How does a warm-air furnace operate? What is one of the principal advantages of this method of heating?

(3) What are the three essential parts of a direct-steam heating system?

(4) In what form is the heat carried from the boiler to the rooms which are to be warmed? What happens to the steam when its heat is given up?

(5) Why is it necessary to remove the air from a steam-heating system?

(6) What is a vacuum system? Describe the method of operation of one type.

(7) How does indirect steam heating differ from direct? State its principal advantage.

(8) What is meant by exhaust steam heating?

(9) Give some of the advantages of hot water heating. What is an expansion tank, and what is its use?

(10) How is the water circulated through the heating mains in large buildings?

(11) What is a system of hot-blast heating?

(12) What is the principal objection to the use of electricity for heating?

CHAPTER III

Boilers

The term boiler, as used in heating, applies to those for heating water as well as for generating steam.

Boilers commonly used for heating may be divided into two classes, those of cast iron, which include the many forms of house-heating, and sectional boilers; and the return tubular type, which is constructed of wrought iron.

Types of Boilers. A simple form of cast-iron boiler for use in dwellings of small and medium size is shown in Fig. 3. This is circular in form, of portable type, the heating surface, furnace, and

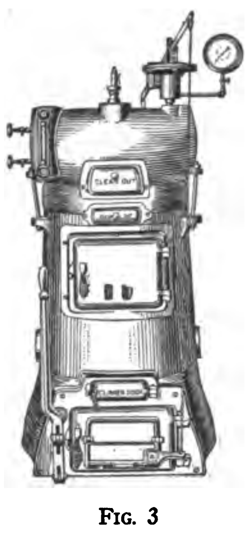


Fig. 3

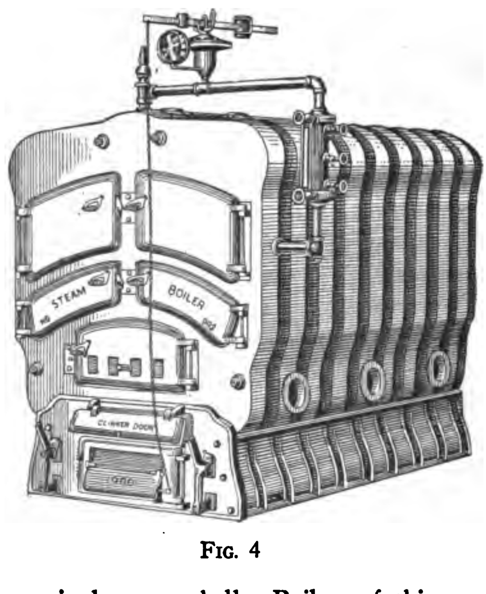


Fig. 4

ashpit being contained in a single outer shell. Boilers of this general form are commonly used for cottages and small to medium sized dwellings, although made of sufficient capacity to carry 1,500 square feet or more of direct steam radiation. They

are commonly equipped with shaking grates, automatic damper regulator, pressure gauge, pop safety valve, water glass, and try cocks, all of which are shown in the cut.

Fig. 4 illustrates a boiler of the sectional type. Although made in small sizes, they are especially adapted to large dwelling houses, stores, churches, and small school buildings. The rated capacity of boilers of this type commonly runs from 5,000 to 8,000 square feet of direct steam radiation.

Being made up of sections, the length can be changed, within certain limits, to meet varying requirements. In the particular make of boiler shown, the width of grate in the different sizes ranges from

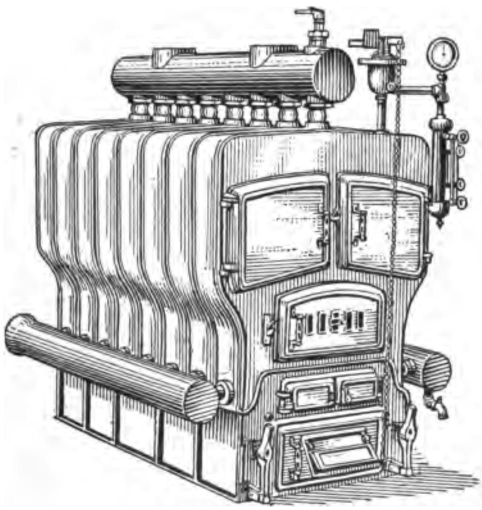


FIG. 5

15 to 48 inches, and the ratings for direct steam from 300 to 8,500 square feet of radiation. The steam outlets are in the top of the sections, and the return openings for receiving the condensation in the side near the bottom, as shown. The general equipment of trimmings is practically the same as in Fig. 3. The boiler shown in Fig. 5 is similar in construction to the one just described, except the sections are connected with drums at both sides near the bottom, and also at the top, as indicated. The steam supply mains are taken from the upper drum, and the condensation is returned to either or both of the lower ones.

Return tubular boilers are generally used for steam heating in buildings of large size, where it would be necessary to use more than two sectional boilers. Some engineers make a practice of using this type of boiler for all plants having the equivalent of 5,000 square feet and over of direct radiation. A return tubular boiler with a section of its setting is shown in Fig. 6. The boiler proper consists

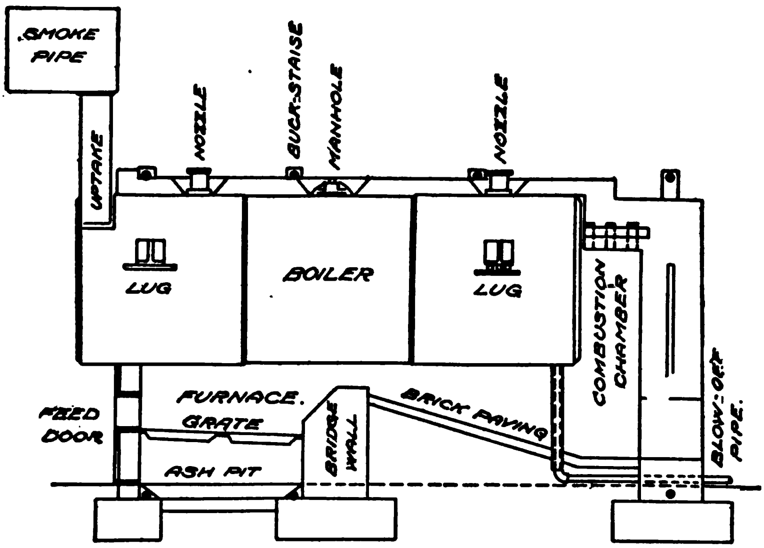


FIG. 6

of a cylindrical shell of wrought iron or steel with heads of the same material, and filled with a large number of tubes, as shown in Fig. 7, which represents an external view of one of the heads. They require a brick setting of the general form shown in Fig. 6. The fire is below the front portion of the shell and the flame and hot gases pass backward over the bridge wall into the combustion chamber, then forward through the tubes, which are surrounded by water, and into the smoke-pipe through the uptake at the front. This form of boiler, when properly proportioned, is efficient, easily cared for, and of moderate cost; hence, is used extensively in low-pressure heating where a considerable volume of steam is required.

General Proportions of Cast-Iron Boilers. The efficiency, that is, the proportion of heat in the fuel utilized, as compared with

that in the total amount of fuel burned, depends largely upon the general construction and form of a boiler and upon the relative areas of the grate and heating surfaces. The average cast-iron boiler of good design has an efficiency of about 60 per cent., which means that the heat obtained from 60 out of every 100 pounds of coal burned in the furnace is used in heating water and generating steam,

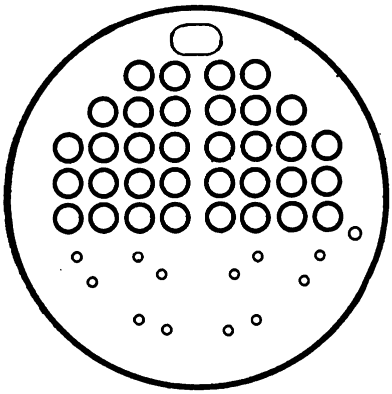


FIG. 7

while the heat from the remaining 40 pounds goes up the chimney. The ratio of the heating surface to the grate area commonly runs from 15 to 25 in well-made boilers of this class.

General Proportions of Tubular Boilers. Tubular boilers are commonly made in sizes up to 72 inches in diameter. The length of the tubes is varied according to the capacity required, but in general, should not very greatly exceed three times the diameter of the shell. The ratio of heating to grate surface is somewhat larger in tubular boilers than in the case of small cast-iron boilers, owing to the higher rate of combustion employed. It is evident that there must be a certain relation between the weight of coal burned and the amount of surface provided to absorb the heat which is given off in the process of combustion. With the rates of combustion commonly employed in boilers of this type it is customary to provide from 30 to 40 square feet of heating surface for each square foot of grate.

With small house-heating boilers it is the usual practice to add fresh fuel at periods of considerable length, and burn it slowly with little or no attention between the periods of firing; hence, a larger

grate area, in proportion to the amount of coal burned, is required than with a tubular boiler which usually has a fireman in attendance all of the time.

Strength of Boilers. The majority of small cast-iron boilers are designed for low-pressure heating, which ordinarily ranges from 1 to 5 pounds per square inch. If it is desired, for any reason, to carry a pressure much above 10 pounds, information should be obtained from the makers as to the safe maximum pressure which may be carried by the boiler in question. The tubular boilers used for heating are commonly designed to carry a working pressure, when new, which allows a wide margin of safety, and provides for the weakening effect of corrosion. When made up with double or triple riveted butt-joints, the shell plates should not be less than 5/16 inch thick for diameters up to 54 inches, and 3/8 inch for larger sizes up to 72 inches in diameter.

Some engineers prefer to add an extra 1/16 inch to the above thickness as an additional precaution against corrosion and to increase the life of the boiler. But so far as strength is concerned, when the boiler is new, the lighter weights given above are ample.

The heads are commonly made 1/8 inch thicker than the shell plates, and that portion above the tubes is strengthened by means of "diagonal" or "through" braces.

In the case of diagonal bracing, one end of the stay is riveted directly to the head, or attached by means of a pin to a piece of T iron riveted to the head, while the other end is riveted to the shell, the body of the brace being carried back on an angle. In the best class of work solid steel braces are used, riveted directly to the boiler head. Such an arrangement is shown in Fig. 7, the rivet heads appearing above the tubes.

For boilers of a larger size, through bracing is more commonly employed.

In this case the stays extend entirely through the boiler, from end to end, and are provided with heavy washers and nuts outside the heads, which are stiffened with crossbars of channel iron. A combination of diagonal and through bracing is often used for boilers of medium size. A very satisfactory arrangement is to use diagonal bracing for diameters up to and including 48 inches, a combination of diagonal and through bracing for those 54 and 60 inches in diameter, and all through bracing for 66 and 72 inch boilers.

Rating of Cast-Iron Boilers. The power or rating of a cast-iron boiler is generally given in the square feet of direct radiating surface which it will supply. This in turn depends upon the amount and arrangement of the heating surface, the ratio of heating to grate surface, and also to a considerable extent upon the care which the boiler receives and the general method of firing. As all of these vary more or less, it is customary to assume average conditions for boilers of different size and base the capacity upon the square feet of grate surface.

In doing this, boilers may be divided into four classes according to their size, and an average rate of combustion assumed for each class. By rate of combustion is meant the pounds of coal burned per square foot of grate per hour.

The amount of heat given off in the combustion of one pound of good anthracite coal is slightly over 13,000 *TU,* so if the efficiency of the boiler is 60 per cent., about 8,000 *TU* from each pound of coal burned are available for heating purposes. Hence, if the size of grate and rate of combustion are known, the capacity of the boiler in *TU* is easily computed.

In order to find the square feet of radiating surface which a boiler will supply, it may be assumed that each square foot of direct steam radiation requires 250 *TU* per hour, and each square foot of direct hot-water radiation 170 *TU*. In determining the size of boiler to supply indirect radiation, count each square foot of surface as being equal to 2 square feet of direct surface. Table III gives the average rate of combustion for boilers of different size.

TABLE III

1 Size of grate in square feet	2 Pounds of coal burned per sq. foot of grate per hour	3 TU supplied for heating per hour, per sq. foot of grate
Class A, 1 to 4	3	24,000
Class B, 5 " 10	4	32,000
Class C, 11 " 15	5	40,000
Class D, 16 " 20	6	48,000

Rule—To find the square feet of radiation which a cast-iron boiler will supply, multiply the square feet of grate by the *TU* supplied by 1 square foot, for the class of boiler under consideration (see Table III, column 3), and divide the result by 250 for direct steam; 170 for direct hot water; 500 for indirect steam, and 340 for indirect hot water.

Examples:

(1) A cast-iron boiler has 8 square feet of grate surface; how many square feet of direct steam radiation will it supply?

Solution.—$(8 \times 32{,}000) \div 250 = 124$ sq. ft.

(2) A boiler has a grate 36″ x 48″ in size; how many square feet of indirect steam radiation will it supply?

Solution.—$3 \times 4 = 12$ square feet of grate, and $(12 \times 40{,}000) \div 500 = 960$ sq. ft.

(3) A building has 400 square feet of direct hot water radiation and 300 square feet of indirect; how many square feet of grate surface will be required in the boiler?

Solution.—Total heat required to supply the radiation is $(400 \times 170) + (300 \times 340) = 170{,}000$ *TU* per hour.

We must now assume the probable class to which the boiler belongs, and make a trial division by the corresponding number in column 3 of Table III.

Assuming the boiler to be in Class B, we divide by the corresponding value in column 3, which gives $170{,}000 \div 32{,}000 = 5.3$ sq. ft.

Referring to column 1, we find that the size of grate found comes within the limits of the class assumed, and is therefore correct.

(4) The steam radiation in a building is made up of 600 square feet of direct surface, and 800 of indirect; how many square feet of grate surface will be required?

Solution.—Total heat required is $(600 \times 250) + (800 \times 500) = 550{,}000$ *TU* per hour.

Assuming the boiler to be in Class B, we divide by 32,000, which gives $550{,}000 \div 32{,}000 = 17$ sq. ft. Looking in column 1 we find the result too large for a Class B boiler, so must make another trial,

using 40,000 for a divisor, which corresponds to Class C. This gives $550{,}000 \div 40{,}000 = 14$ sq. ft., which is within the required limits.

Rating of Tubular Boilers. Tubular boilers are commonly rated on a *horse-power* basis, one horse power being the capacity to evaporate 34.5 pounds of water per hour into steam at atmospheric pressure. This requires in round numbers 33,000 *TU*.

Hence, to find the boiler horse power in any given case, first determine the *TU* required, the same as for a cast-iron boiler, and divide the result by 33,000.

EXAMPLE:

(5) A building requires 2,000 square feet of direct steam radiation, and 3,000 feet of indirect; what boiler horse power will be required?

SOLUTION.—Total heat to be supplied is $(2{,}000 \times 250) + (3{,}000 \times 500) = 2{,}000{,}000$ *TU* per hour, and $2{,}000{,}000 \div 33{,}000 = 61$ H. P.

(6) How many square feet of direct steam radiation will be supplied by a 40-H. P. steam boiler?

SOLUTION.—$(40 \times 33{,}000) \div 250 = 5{,}280$ sq. ft.

Dimensions of Tubular Boilers. Under the conditions of average heating practice, it is customary to provide 15 square feet of heating surface per horse power in boilers of this type; this surface being made up of the lower half of the shell, the rear head, and the tubes. The size and number of tubes for a given diameter of shell is a matter of experience rather than computation, and will be given in tabular form.

The required grate area will depend upon the strength of chimney draft, the ratio of heating to grate surface, the frequency with which the boiler is cleaned, and the skill in firing. Under average conditions the size of grate for heating boilers may be computed on a basis of about 0.4 square foot per horse power.

Table IV gives dimensions of boilers of different diameters and lengths, with their rated capacity in horse power. The grates are based on 0.4 square foot per H.P., but as it is customary to vary the grate dimensions in multiples of 6 inches, they will be found to vary from this somewhat in certain cases.

TABLE IV

Diameter of boilers	Diameter of tubes	Number of tubes	Length of tubes	Horse power of boiler	Size of grate
42″	3″	34	10′	20	36″ x 42″
			11′	22	36″ x 48″
			12′	24	36″ x 48″
			13′	26	36″ x 48″
48″	3″	44	11′	33	42″ x 48″
			12′	35	42″ x 54″
			13′	38	42″ x 54″
			14′	40	42″ x 60″
54″	3″	54	12′	38	48″ x 54″
			13′	41	48″ x 54″
			14′	44	48″ x 54″
			15′	47	48″ x 60″
60″	3″	72	13′	52	54″ x 60″
			14′	56	54″ x 60″
			15′	60	54″ x 66″
			16′	64	54″ x 66″

After computing the horse power required in any given case, the size best adapted to the local conditions can be chosen from Table IV. In plants of considerable size, it is better to use two or three boilers set in a battery than a single large one. This makes it possible to regulate the size of the plant to correspond with the work to be done, which is often a matter of much convenience. During the spring and fall, when the amount of steam required for heating is comparatively small, one of the boilers can be shut down, and again, if three boilers are used, it is usually possible in case of a breakdown to force the other two sufficiently to do the whole work temporarily.

Trimmings. Each boiler in a battery should be provided with its own safety-valve, pressure-gauge, water-glass, and try-cocks. An adjustable hand damper is commonly placed in the smoke connection

from each boiler for equalizing the draft, and a balanced damper in *the main* smoke pipe, operated by an automatic regulator, for maintaining a constant steam pressure.

Fusible plugs, which melt and give an alarm in case of low water, and at the same time quench the fire, are usually called for in the best class of work. Their location depends upon the type of boiler. In horizontal tubular boilers they are placed in the rear head slightly above the top of the upper row of tubes.

Feed and Blow-off Connections. In low-pressure heating work a connection with town or city water pressure is all that is necessary for feeding a boiler. The feed-pipe should be provided with gate and check valves, the former being placed next to the boiler. In larger plants, where a return pump is used, connections should be so made that water can be admitted directly to the boilers under city pressure, or discharged into the receiving tank and pumped in with the condensation. Means should be provided for draining the boiler into a dry well or sewer. If the latter method is employed a blow-off tank should be used for cooling the water before it enters the earthen sewer pipes.

Foundations and Settings. Cast-iron boilers require only a foundation of brick or concrete, and a covering of some good insulating material, like carbonate of magnesia or asbestos.

Tubular boilers, on the other hand, require both a foundation and brick setting, as shown in Fig. 6.

Detail drawings for boiler settings of different size, and for both heating and power work, can be obtained from the makers of the boilers.

Chimneys. A good chimney draft is very important to the successful operation of any kind of a boiler. Although the chimney flue is usually considered a part of the building construction, the heating engineer should have an opportunity to check the dimensions, in order to make sure that it is adapted to the proposed boiler plant. Table V, given by Prof. R. C. Carpenter, may be used for determining the height and area of chimneys for cast-iron and tubular boilers, and is based on the square feet of direct radiation to be supplied by the boiler. If the building contains indirect surface, count it as double the amount of direct, as already noted in determining the boiler capacity. The numbers given in the following table represent the diameter of a round flue or the side of a square flue, in inches.

TABLE V.

Direct radiation		Height of chimney in feet					
Steam sq. ft.	Water sq. ft.	20	30	40	50	60	80
250	375	8	7	7	7	6	6
500	750	10	9	9	8	8	7
750	1,150	11	11	10	10	9	9
1,000	1,500	13	12	11	11	11	10
1,500	2,250	15	14	13	13	12	12
2,000	3,000	17	16	15	15	14	13
3,000	4,500	21	19	18	17	17	16
4,000	6,000	24	22	21	20	19	18
5,000	7,500	26	25	23	22	21	19
6,000	9,000	28	27	25	23	23	21
7,000	10,500	30	29	27	26	25	23
8,000	12,000	32	31	29	27	26	24

This table is adapted to both cast-iron and tubular boilers, as the chimney dimensions are based on the square feet of radiation instead of on the capacity of the boiler.

TEST QUESTIONS:

(1) What two types of boilers are commonly used for heating work? Which is generally used for large buildings?

(2) What is meant by the efficiency of a boiler? What is the average efficiency of a cast-iron boiler?

(3) What two methods are used for bracing or staying the heads of tubular boilers?

(4) How is the capacity of a cast-iron boiler commonly expressed? Define a boiler horse power.

(5) How are the required capacities of both cast-iron and tubular boilers determined from the radiation to be supplied?

(6) How many square feet of heating surface are required per horse power in tubular boilers used for heating? How many square feet of grate area?

(7) What trimmings are required for each boiler?

(8) How are the feed and blow-off connections made?

(9) What is required in the way of foundations and settings for cast-iron boilers? What for tubular boilers?

CHAPTER IV

Radiation

The term *radiation* includes all forms of heating or radiating surface used for the warming of buildings, both for steam and hot water. Radiators are made in many different forms, and are constructed of cast iron, pressed steel, and of wrought-iron pipe with cast-iron fittings.

They may be divided into two general classes, known as ***direct*** and ***indirect.***

Direct Radiators. The term direct radiator is applied to all forms which are placed directly in the rooms to be heated, whether of the cast-iron sectional type or made up of pipe coils extending along the walls or supported near the ceiling.

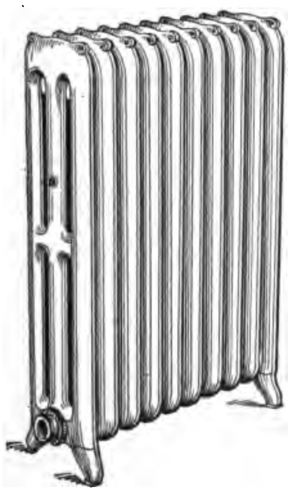


FIG. 8

FIG. 9

The most common form of direct steam radiator is shown in Fig. 8. This is made up of cast-iron sections or slabs joined at the bottom by special nipples. Steam is usually admitted at one end near the bottom, as indicated by the opening shown in the cut. The con-

densation is sometimes drained off through a similar opening at the opposite end, and sometimes through the lower part of the steam opening back into the supply riser, as will be described in a later chapter. Radiators of this type are made in various heights, commonly running from 18 to 45 inches in the standard forms, although made as low as 12 or 13 inches for special locations. The width also varies, different widths being expressed by the number of *columns* which a single section contains; for example, Fig. 8 is a three-column radiator. The length may be varied by adding sections to give the required heating surface.

Pressed-steel radiators are similar in appearance to those made of cast iron. They are made of thin sheets of steel, pressed to the required form, joined by special seams, and galvanized both outside and inside. A radiator for hot water heating is shown in Fig. 9. This is

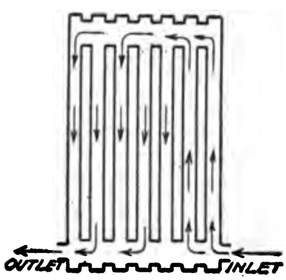


FIG. 10

similar in construction to Fig. 8, except the sections are joined at the top as well as at the bottom. This is necessary in order to secure a proper circulation of water within the radiator. The path which the water follows when passing through a radiator of usual form is shown in diagram in Fig. 10. In this case the hot water is supplied at the bottom of the radiator on the right-hand side, and passes upward through the first two or three sections as indicated by the arrows. It then flows along the top passage and downward through the remaining sections, replacing the cooler water, which flows into the lower passage and through the outlet into the return.

Another form of cast-iron radiator is designed especially for attaching to the wall.

This is a very useful pattern, as it is often desirable to keep the floor free of radiators. As the sections are only about 3½ inches in thickness, very little space is required, which makes them especially adapted to toilet rooms, corridors, chambers, etc. The interior construction of wall radiators is such that they may be used for either steam or hot water.

Some of the older forms of radiators are made up of 1-inch wrought-iron pipes, screwed into a cast-iron base and furnished with a lattice-work top, or screen, of the same material. The pipes commonly used for this purpose contain a thin metal diaphragm running lengthwise from the bottom nearly to the top, thus separating the tube into two parts, and forming a loop connected at the top, for the circulation of steam.

If simply a straight tube were used with a "dead end" it would become air bound. Sometimes the diaphragms are omitted and the tubes joined at the top in pairs by means of return-bend fittings.

This arrangement operates satisfactorily so far as steam circulation is concerned, but it is difficult to construct radiators in this manner so that they will remain tight under steam pressure.

This type of radiator is but little used, except in special cases.

Circulation Coils. Where it is desired to extend the radiating surface over a considerable amount of space, and where the appearance is not objectionable, coils of wrought-iron pipe are used instead of cast-iron radiators. This form of radiation is used extensively in shops and factories, and also in schoolrooms where it is desired to

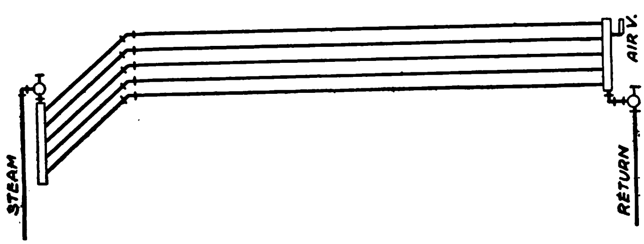


FIG. 11

distribute the heat along the outer walls under the windows. A common form of wall coil is shown in Fig. 11. This arrangement is used where the pipes can be carried around a corner, thus giving

sufficient flexibility to offset the effects of expansion. The ends of the pipes are screwed into special cast-iron headers, and the whole supported on hook-plates attached to vertical wooden cleats. The usual method of making the steam and return connections to a coil of this kind is shown in the cut.

When the entire coil must be placed upon the same side of a room, provision for expansion must be arranged for in some other way. Fig. 12 shows a method commonly used in shops and similar buildings where the appearance is not objectionable. This is called a

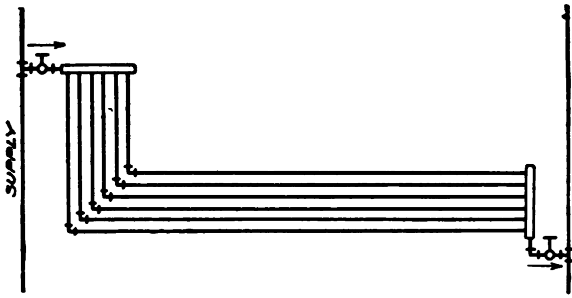


FIG. 12

mitre coil, and is connected up for steam and return in the manner shown. Another form of coil for a single wall is illustrated in Fig. 13. This is more pleasing in appearance than the one just described, and is more frequently used in schoolhouses and stores; it is commonly termed a *trombone* or *return-bend* coil. It is often necessary

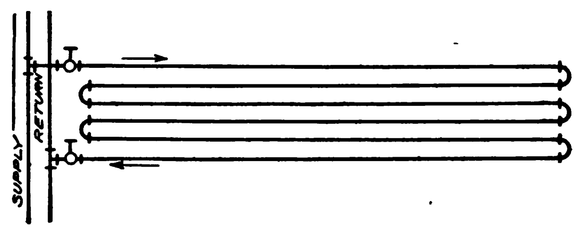


FIG. 13

in basement rooms to hang the coils from the ceiling in order to bring them above the water line of the boilers in gravity-return systems. In cases of this kind, and in shops where the entire wall space is occupied, mitre coils are commonly used, placed on the side and pitched slightly toward the return end.

Another form of heater sometimes used in special cases, where a large amount of heating surface is to be provided in a limited space, is the *box coil.* This is made up of a number of return-bend coils, like that in Fig. 13, placed side by side with the supply and return ends connected with the same cast-iron headers.

All of the forms of circulation coils shown or described can be used for hot water as well as steam, when properly graded and connected.

Location of Direct Radiators. In general, radiators and coils should be placed in the coldest parts of the rooms to be warmed. In the case of an average-sized room in a dwelling house this is not of so much importance, and the radiator is generally located with reference to the position of the furniture.

In a small or medium sized room the heat will be pretty evenly distributed, whatever the location of the radiator. Wall coils, on the other hand, are generally placed along the outer walls of a room to counteract the cold drafts from the windows.

Painting and Bronzing Radiators. Direct radiators and coils are usually finished by the steamfitter, although this part of the work can generally be done in a much more satisfactory manner by the painters. Direct radiators are often objected to by architects and others on account of their unsightly appearance, but if properly decorated in harmony with their surroundings this objection can, in a large measure, be removed.

Indirect Radiators. This term includes all heating surfaces placed in ducts and flues, whether the air passing over them is supplied by a fan or is moved by gravity. As commonly used, a gravity

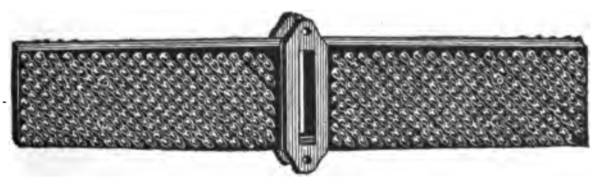


FIG. 14

flow is usually understood, unless otherwise stated. Indirect radiators are made in many forms, one of the most common being shown in Fig. 14. This is covered with small projections to increase the heating surface, and for this reason is called a *pin* radiator. A number

of sections joined together, as in Fig. 15, is called a stack. The radiator shown in Fig. 14 may be used either for steam or hot water,

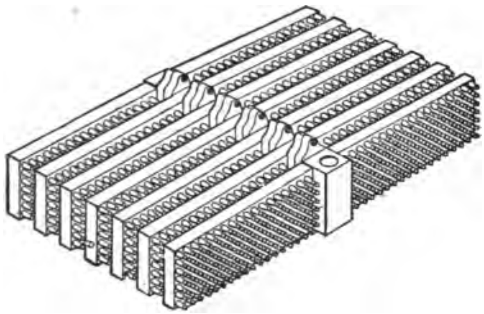


Fig. 15

as desired. Another form of indirect radiator, designed especially for hot water heating, is illustrated in Fig. 16. The extended surface

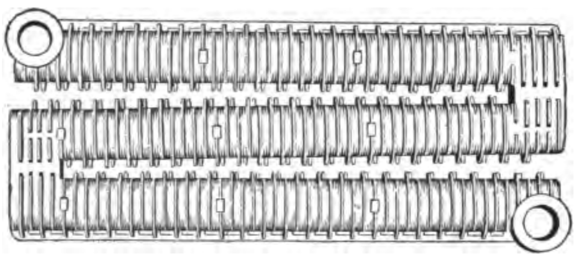


Fig. 16

in this pattern is in the form of fins or flat blades, instead of pins, as in the one above described.

Some radiator sections are flanged and put together with bolts, as in Fig. 15, while others are joined with screwed nipples.

Stack Casings. Indirect heaters are usually encased in galvanized iron, as shown in Fig. 17. This is of such form as to cause the entering air to pass between the sections as indicated by the arrows. In the case of dwelling houses, and similar work, where the stacks are of medium size, they are usually supported by hangers attached to the joist at the basement ceiling. Where large heating stacks are required, as in school buildings, they are generally placed on iron beams which rest in the side walls of a brick chamber built up from the

floor, and which also takes the place of the galvanized iron casing. The top of a heating chamber of this kind is commonly lined with galvanized iron above the stack, although plastic asbestos, or some similar material, on a light iron frame, is sometimes used.

Direct-Indirect Radiators. A direct-indirect radiator consists of an ordinary direct radiator with a special casing around the lower half, which being connected with the outer air is made to furnish a

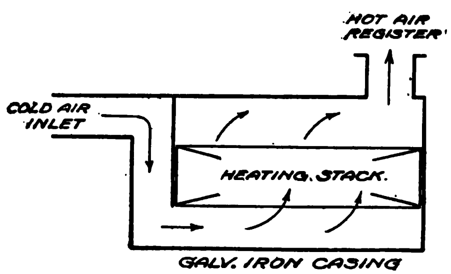


FIG. 17

certain supply for ventilating purposes, in a similar manner to the ordinary form of indirect stack. Radiators of this form are used where it is difficult to run flues, or in cases where it is desired to ventilate one or more rooms in a building not supplied with a system of indirect heating. When ventilation is not required, the radiator may be used in the usual manner for direct heating, by simply throwing a switch damper.

Vent-Flue Heaters or Aspirating Coils. It is often necessary in indirect heating to place coils or heaters in the vent flues to strengthen the draft.

One of the best forms for this purpose is made up of wrought-iron pipes, having the internal diaphragm, already described, screwed into a cast-iron base or header. The length of the pipes should be equal to at least twice the depth of the flue, so that when placed in an inclined position the free area between the pipes will be equal to the area of the flue. Although the required heating surface for an aspirating coil may be computed for any given condition, it is usually sufficient to use a heater made up of 1-inch pipes spaced 2½ or 3 inches on centers, and having a length equal to 2½ times the depth of the flue. A heater of these dimensions should contain two rows of pipe,

and be placed in the flue in a position inclined from the vertical sufficiently to fill the entire space.

Computing the Size of Direct Radiators. The amount of radiating surface required to warm a room depends upon the heat lost in a given time by transmission through the walls and glass, and by leakage around windows and doors. This, in turn, varies with the difference between the inside and outside temperatures, the thickness and material of the walls, and the general tightness of the building construction. Tables have been prepared, based on experiment, which give the approximate transmission of heat in *TU* for a large number of building materials of different thicknesses. By means of these the total heat loss per hour from a room may be computed, and this loss divided by the number of *TU* given off per hour per square foot of radiating surface will give the required size of the radiator in square feet. The quantity of heat given off in this manner by different kinds of radiation is called the *efficiency,* which may be taken as 250 *TU* for direct steam, and 170 *TU* for direct hot water, as noted in Chapter III.

Taking the average heat loss from wood and brick buildings of good construction, it is found that 1 square foot of direct steam radiation should be provided for each 3 square feet of glass, and for each 10 square feet of outside wall surface, in order to maintain an inside temperature of 70° with zero weather outside.

For direct hot-water radiation, use the figures 2 and 8 in place of 3 and 10. This applies to rooms on the south side of a building; for other exposures multiply the results by the following factors:

North	1.3	South	1.0
East	1.1	West	1.2

When the building is of poor construction, with loose joints around doors and windows, multiply the results by 1.3.

In measuring the wall surface of a room take only that which is exposed to the outside temperature after the window area has been deducted.

EXAMPLES:

(1) The exposed net wall surface of a room is 2,000 square feet, the glass surface 300 square feet. The room has a southern exposure. How many square feet of direct steam radiation will be required to warm the room in zero weather?

SOLUTION.—

$$2{,}000 \div 10 = 200$$
$$300 \div 3 = 100$$

Total 300 square feet.

(2) How many square feet of radiation would be required for a similar room with a northern exposure?

SOLUTION.—$300 \times 1.3 = 390$ sq. ft.

(3) A square corner room has a net wall surface of 3,200 square feet, and 800 square feet of glass surface. One side is exposed to the north and the other to the west. How many square feet of direct hot-water radiation will be required to warm the room in zero weather?

SOLUTION.—

$$3{,}200 \div 8 = 400$$
$$800 \div 2 = 400$$

800

Now, half the room has a northern exposure, and half a western exposure, so one-half the radiation must be multiplied by 1.3 and the other half by 1.2, which gives

$$400 \times 1.3 = 520$$
$$400 \times 1.2 = 480$$

Total 1,000 sq. ft.

(4) A room in a *poorly built* house has one outside wall exposed to the south. The length of the room is 20 feet, and the height 12 feet. There are three windows, each 3 ft. by 6 ft. in size. How many square feet of direct steam radiation will be required to warm the room in zero weather?

SOLUTION.—Total exposed surface, $12 \times 20 = 240$
exposed glass, $3' \times 6' \times 3 = 54$

Net wall, 186 sq. ft.

Radiation for wall surface, $186 \div 10 = 18.6$
" " glass surface, $54 \div 3 = 18$

Total 36.6 sq. ft.

As the house is poorly built, the above amount of radiating surface must be multiplied by 1.3, which gives

$$36.6 \times 1.3 = 48 \text{ sq. ft.}$$

When a room has a cold attic above it or an unheated basement below, the size of radiator computed by the above methods should be multiplied by 1.1.

EXAMPLE:

(5) A house having ground dimensions 30 ft. by 40 ft., is two stories in height, each being 8 ft. One-fourth of the total exposed surface is glass. The building is well built, but has a cold attic. How many square feet of direct hot-water radiation will be required to warm the building in zero weather?

SOLUTION.—

Total exposed surface,	$(30 + 30 + 40 + 40) \times 16 =$	2,240
exposed glass,	$2{,}240 \times 0.25 =$	560
Net wall,		1,680 sq. ft.

Radiation for wall surface,	$1{,}680 \div 8 =$	210
" " glass "	$560 \div 2 =$	280
Total		490
Increasing for cold attic,	$490 \times 1.1 =$	539 sq. ft.

As the building is exposed on all four sides, the radiating surface must be increased by a factor which is the average of the factors for north, east, south, and west, or $(1.3 + 1.1 + 1.0 + 1.2) \div 4 = 1.15$.

This gives a total of $539 \times 1.15 = 620$ sq. ft.

Computing the Size of Indirect Radiators. While the efficiency of an indirect radiator is practically twice that of a direct radiator, a larger amount of heating surface is required for warming a given room, because the air passing over it has first to be warmed from the outside temperature up to 70° before heat can be stored in it for purely warming purposes. In the case of dwelling houses, and similar buildings, the simplest way is to first compute the size of a direct radiator for warming the room and multiply this by 1.5. This applies to both steam and hot water heating. In the case of schoolhouses, where large volumes of air at moderate temperatures are

supplied for ventilation, it is customary to provide about 300 square feet of indirect radiation for each standard class-room, a standard class-room being approximately 28 ft. by 32 ft. in size and seating 50 pupils. A direct-indirect radiator should be made 1.25 times as large as a direct radiator for the same room.

EXAMPLES:

(6) A room on the south side of a house has 600 square feet of net wall surface and 210 square feet of glass surface. How many square feet of indirect steam radiation will be required to warm it in zero weather?

SOLUTION.—$600 \div 10 = 60$
$210 \div 3 = 70$

130 sq. ft. of direct, or $130 \times 1.5 = 195$ sq. ft. of indirect radiation.

(7) How many square feet of indirect water radiation would be required to heat the same room?

SOLUTION.—$600 \div 8 = 75$
$210 \div 2 = 105$

180 sq. ft. of direct, or $180 \times 1.5 = 270$ sq. ft. of indirect radiation.

Dimensions of Radiators. After computing the square feet of heating surface which a radiator is to contain, this is marked on the plans, together with the height, and also the width, whether one, two, or three column. If pipe coils are used, the square feet of heating surface should be reduced to linear feet of pipe, and the length and number of lines marked on the plan. To reduce square feet of heating surface to linear feet, multiply by the following factors: 1-inch pipe, 3; 1¼-inch pipe, 2.3; 1½-inch pipe, 2. For example—100 square feet of heating surface requires $100 \times 3 = 300$ linear feet of 1-inch pipe, or $100 \times 2.3 = 230$ linear feet of 1¼-inch pipe.

TEST QUESTIONS:

(1) What is the difference between a direct and indirect radiator? What is a direct-indirect radiator?

(2) Describe two different kinds of direct radiation. In what kinds of buildings are circulation coils used?

(3) What is an aspirating coil? Describe a common form.

(4) How is the size of a direct steam radiator computed for a room having a southern exposure, in a well-built house?

(5) How computed for other exposures? Give the correction factors for north, east, and west.

(6) What is the effect of a cold attic upon the size of the radiators in the rooms directly below? How is this provided for?

(7) What correction is made to the size of the radiators if the house is poorly built?

(8) In what way does method of computing the size of a direct hot water radiator differ from steam?

(9) How is the size of an indirect radiator computed? Also a direct-indirect radiator?

(10) State method of reducing square feet of heating surface to linear feet of 1¼-inch pipe.

CHAPTER V

Pipe and Fittings

Wrought Iron Pipe. Wrought-iron pipe of standard weight is used for practically all heating work, except in inaccessible places, such as concealed risers and underground returns, which are usually made extra heavy.

Although commonly termed wrought iron, most of the pipe used is really a soft steel. This is somewhat less expensive than wrought iron, and, under ordinary conditions, the better grades seem to fulfill all requirements.

Table VI gives useful data relating to standard weight pipe, and will be found convenient in the design of heating systems. Only such sizes are included as are commonly employed in plants of ordinary size.

TABLE VI

Nominal diameter, inches	Outside diameter, inches	Inside diameter, inches	Length of pipe per square foot of outside surface, feet	Inside area, square inches	Weight per foot, pounds
¾	1.05	0.82	3.64	0.53	1.13
1	1.31	1.05	2.90	0.86	1.67
1¼	1.66	1.38	2.30	1.50	2.26
1½	1.90	1.61	2.01	2.04	2.69
2	2.37	2.06	1.61	3.35	3.60
2½	2.87	2.47	1.33	4.78	3.77
3	3.50	3.07	1.09	7.39	7.55
3½	4.00	3.55	0.95	9.89	9.05
4	4.50	4.03	0.85	12.7	10.7
5	5.56	5.04	0.63	20.0	14.5
6	6.62	6.06	0.58	28.9	18.8
7	7.62	7.02	0.50	38.7	23.3
8	8.62	7.98	0.44	50.0	28.2
9	9.62	9.00	0.39	63.6	33.7
10	10.75	10.00	0.35	78.8	40.1

The following examples illustrate some of the ways in which Table VI is used in practical work.

EXAMPLES:

(1) How many square feet of external heating surface in forty 4-inch pipes, each 8 feet long?

SOLUTION.—Total length of pipe, $8 \times 40 = 320$ ft., and $320 \div 0.85 = 376.5$ sq. ft.

(2) A heating coil contains sixty 1½-inch pipes 5 feet long. What is its weight?

SOLUTION.—Total length of pipe, $5 \times 60 = 300$ ft. Weight, $300 \times 2.69 = 807$ pounds.

(3) Four 4-inch pipes are joined together into a single main. What diameter of pipe should be used to give approximately the same internal area?

SOLUTION.—Total area of pipes, $4 \times 12.7 = 50.8$ square inches. The area of an 8-inch pipe is 50 sq. in., and is the size to be used.

Brass and Copper Pipe. Brass pipe is used in the best class of work, around boiler fronts, between pumps and boilers, and in

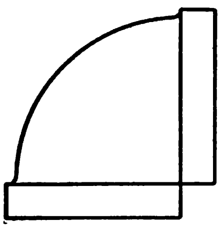


FIG. 18

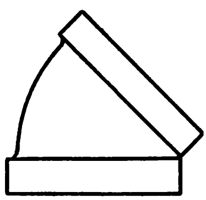


FIG. 19

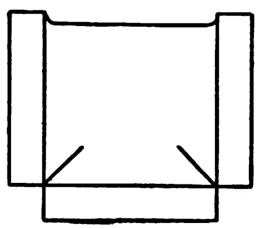


FIG. 20

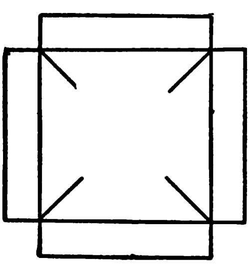


FIG. 21

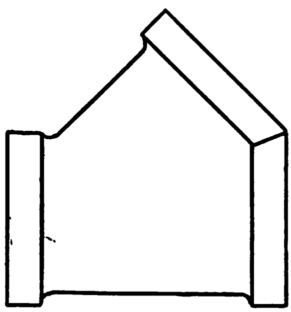


FIG. 22

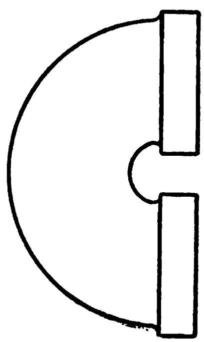


FIG. 23

all cases where hot water is to be handled. Copper tubing is also employed to some extent in a similar manner, but more especially in connection with hot water heaters for laundry purposes.

Fittings. Fittings in a great variety of forms are used for making the pipe connections. These are made of cast iron, both for screwed and flanged joints.

Some of the more common forms are shown in Figs. 18 to 23. The 90-degree elbow (Fig. 18) is used for making right-angled bends, and the 45-degree elbow (Fig. 19) for making one-eighth bends. The latter is frequently used in hot-water systems where it is desired to avoid abrupt turns in the direction of flow on account of the increased friction.

The tee (Fig. 20) is used in separating a main into branches or for gathering a number of lines into a single pipe. The cross (Fig. 21) is used for a similar purpose, but not so frequently.

The Y-branch (Fig. 22) is used in hot-water work instead of the regular tee fitting, for the same reason as the 45-degree elbow. The fitting shown in Fig. 23 is used for making a 180-degree turn, and is employed most frequently in the construction of return bend and

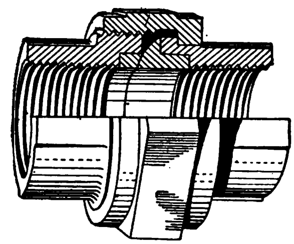


FIG. 24

box coils. Elbows and tees are made with all openings the same size, and also with openings of different sizes, for reducing or enlarging the pipe lines as may be required. Fig. 24 is a *union,* and is used where it is necessary to disconnect the piping occasionally or where it would be difficult to make up the piping with regular fittings. For the larger sizes of pipe flanged unions, put together with bolts, are used instead of screwed pattern, shown in Fig. 24.

Unions and flanges are used for making connections around boilers, pumps, traps, and also with radiators.

The fittings shown in Figs. 18 to 23 are the regular, or short-turn pattern. Long-turn fittings, so called, are commonly used for

hot water heating on account of offering less resistance to the flow of water through them, which is a matter of much importance, especially in gravity systems, where the circulation is naturally weak. Fittings of large size, particularly around boilers and heaters, are usually flanged and bolted instead of being screwed, as it is easier to erect heavy piping in this manner.

Expansion. Wrought-iron pipe expands approximately 1½ inches for every 100 feet in length when heated from 32° to 215°, the temperature of steam at 1-pound pressure. This makes it necessary to provide such means for taking up the expansion as will prevent undue strains at the fittings. It is usually possible in heating work to run the piping in such a manner that it will have sufficient flexibility to overcome the effects of expansion. This is done by providing offsets or loops at the ends of all runs of piping of any considerable length.

Piping of the sizes used in ordinary heating work has considerable "spring," and this may be depended upon to care for the expansion if proper offsets are provided. It is sometimes necessary in the case of long mains of large size to use ***expansion joints***. There are different forms of these, the most common being the slip joint, which is so constructed that the part attached to one section of the pipe slides into a sleeve attached to the next section, thus taking up any lengthening due to expansion. The principal objection to this form of joint is the difficulty of keeping it tight against the leakage of steam and water, but with low pressures this can usually be done without much difficulty.

When an expansion joint of this type is used, one section of the pipe should be securely anchored close by, while the other section is allowed to move freely; otherwise the line of piping will buckle or spring out of line if the joint should stick and refuse to work properly.

Pipe Joints. Screwed joints are commonly made up with a small amount of red or black lead and oil applied to the threads before screwing into place. Flanged joints are provided with gaskets, the best of which are made of rubber mixed with certain heat resisting materials and vulcanized. Sheet packing for high pressures often has a wire gauge insertion for giving additional strength.

Methods of Supporting Pipes. Steam pipes are usually supported by hangers attached to the ceiling above.

Fig. 25 shows two common forms, one for screwing into a wooden joist, and the other for clamping to the lower flange of an iron beam.

Overhead returns are supported in a similar manner, while those at the floor, or in trenches, are usually carried on small iron rolls set

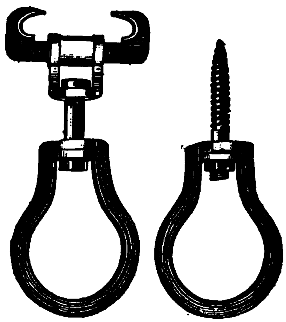


FIG. 25

in iron frames and called pipe chairs. There are other forms for supporting a pipe along the wall of a building, which are used when return pipes are carried near the floor, but not on it.

Grade of Pipes. Steam pipes should be given a slight downward grade in the direction of the flow of steam, so that the water of condensation will be carried along with it to drainage points placed at frequent intervals. Dry or overhead return pipes should be given a downward pitch of at least 1 inch in 10 feet toward the receiving tank or boiler.

Sealed or wet returns do not require any special grade to work properly, but it is customary to pitch them slightly toward the boiler and provide a draw-off connection at the lowest point for draining out the water from the system in case of repairs.

Pipe Covering. The supply and return pipes of both steam and hot-water systems are usually covered with some non-conducting material to prevent heat loss by radiation. This is sometimes omitted in the case of small houses, where a certain amount of heat is desirable in the basement, but in general it is best to insulate both the piping and the boiler. Various materials are used in the manufacture of pipe covering, the more common being carbonate of magnesia, hair, felt, asbestos, mineral wool, and cork. These are formed into a canvas-covered shell about an inch in thickness, and placed around

the pipe, then fastened in place with thin metal bands. Fig. 26 is a short section of covering composed of some compact material like

FIG. 26

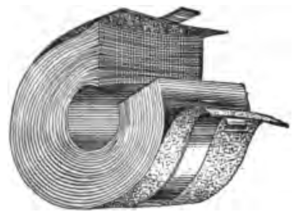


FIG. 27

magnesia or mineral wool, while that shown in Fig. 27 is made up of a number of layers of asbestos paper with air spaces between them.

A good form of commercial covering saves from 75 to 80 per cent. of the heat which would otherwise be lost from the bare pipes. Pipe fittings, steam and water boilers, and tanks, are usually covered with plastic asbestos or magnesia, applied in several thin coats, each being allowed to dry before the application of the next coat. Large surfaces are commonly covered with blocks of insulating material, wired in place, and finished with a plastic covering.

Pipe Sizes. The sizes of supply and return pipes, both for steam and water heating, are determined partly by computation and partly from data obtained by experiment.

As a matter of convenience, such data is usually put in the form of tables giving the square feet of radiating surface which will be supplied by pipes of different sizes under varying conditions. Such tables are given in the chapters on steam and hot water heating.

Vales. The valves used in steam and water heating are commonly known under the heads of *gate, globe, quick opening, check,* and *air* valves.

Gates Valves are of the general form shown in section in Fig. 28. These are so constructed as to form a straight passage through for the flow of steam and water. They are widely used for the mains and branches in both steam and water heating. In the best makes both the gate and valve seats can be renewed when worn.

Globe Valves of the angle pattern (see Fig. 29) are commonly used for making the connections with steam and water radiators; their particular form enables them to take the place of an elbow, and they are frequently used for this reason.

A straightway globe valve offers more resistance to the flow through it than a gate valve, and also forms a pocket in the pipe

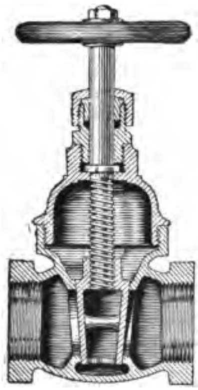


FIG. 28

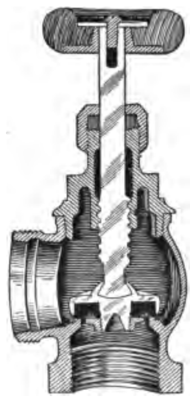


FIG. 29

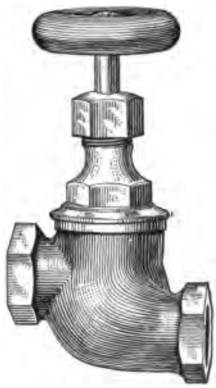


FIG. 30

back of it for the accumulation of condensation. For this reason it should never be used in overhead return pipes unless the stem is placed in a horizontal position, or vertical, with the hand wheel at the bottom.

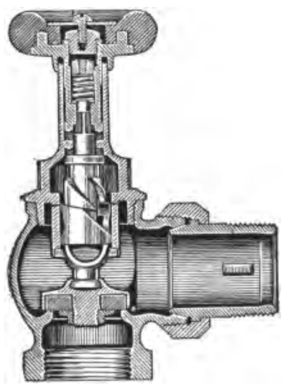


FIG. 31

When it is not possible to use an angle valve at a radiator, the *offset* valve shown in Fig. 30 is generally substituted, especially if the radiator has a single connection.

Quick Opening Valves, so called, are made in several forms, both for steam and water radiators. A pattern adapted to either is shown in Fig. 31. Less than a single turn of the wheel opens or closes the valve.

Check Valves are used wherever it is desired to prevent a reversal of flow in the pipe, as the steam or water can only pass through

FIG. 32

in one direction. A swing check is shown in Fig. 32, from which it is readily seen that the flow must necessarily be in the direction of the arrows.

Check valves are commonly used in the main return near the boiler, in the feed pipe, in the discharge from traps, and in any place where there is a possibility of steam or water "backing up" under certain conditions.

Air Valves are placed upon radiators for removing the air. Two forms of automatic air valves for steam radiators are shown in Figs. 33 and 34. The office of these is to remove the air from a radiator without allowing the steam to pass out. In the first of

FIG. 33

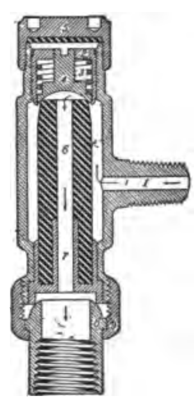


FIG. 34

these, the small valve "a" remains open and allows the air to be forced out by the steam pressure back of it, but closes as soon as hot steam strikes the copper chamber below it; this being partly filled

with a volatile liquid which vaporizes when heated and thus forces up the top of the chamber and closes the valve "a."

In Fig. 34 the action is similar, except in this case the valve is closed by the expansion of a piece of vulcanite.

The path of the air through the valve is indicated by the arrows.

There are many different forms of air-valves, but most of them operate on the expansion principle just described.

TEST QUESTIONS:

(1) What material is used for steam and hot water piping?

(2) For what purposes is brass and copper pipe used?

(3) Name some of the more common forms of pipe fittings. Of what material are they usually made?

(4) What provision must be made for taking up the expansion of steam pipes? Where are pipe anchors used?

(5) How are pipe joints made steam and water tight?

(6) How are steam and return pipes supported? What grade should be given to them?

(7) How is the loss of heat from steam and hot water pipes prevented? What form of covering is used on boilers and tanks?

(8) What advantage has a gate valve over a globe valve? What precaution should be taken when a globe valve is used in an overhead return?

(9) What is a check valve, and where used?

(10) Upon what principle does an automatic air-valve operate?

CHAPTER VI

Low-Pressure Steam Heating

The term "low-pressure steam heating" is commonly applied to systems operating under a pressure of one to ten pounds above the atmosphere, where the radiators are under boiler pressure, and the condensation returned by gravity without the use of traps or pumps.

Low-pressure heating is divided into the direct and indirect systems, and these are again sub-divided, according to the method of making the pipe connections between the boiler and radiators.

Direct Heating. The systems of piping described in the following pages apply especially to direct heating, although there is practically no difference in running the basement mains for a two-pipe direct system and for an indirect system. In fact, indirect radiators may be connected with any of the systems of piping shown, by making slight additions in some cases in the way of return mains, as will be described later.

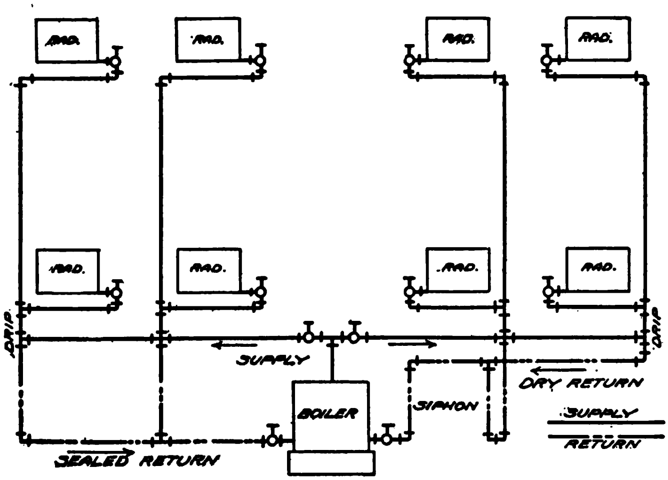


FIG. 35

Single Pipe Relief System. This is one of the simplest methods of piping, and is shown in diagram in Fig. 35.

In this arrangement, as usually employed in dwelling houses and similar buildings, the branches for supplying the different risers are run near the basement ceiling. Single risers are carried to the radiators above, two or more being connected with the same riser when conveniently located. Steam is supplied to each radiator and the condensation removed through a single connection, as shown.

In this arrangement the piping must be made of ample size, because the steam and water are flowing in opposite directions. If the pipes are too small, the velocity of the steam will be increased to such a point that particles of water from the returning condensation will be picked up and carried back into the radiator, resulting in "water hammer" and poor circulation. The connections between the risers and radiators are commonly made as in Fig. 35, to give flexibility and prevent leaks being formed at the joints by the expansion and contraction of the risers. The bottom of each riser is dripped into a main return which is carried back to the boiler. The pipe at the left, in the cut, is carried below the water line of the boiler and is called a "sealed" or "wet" return. The pipe at the right is carried overhead, above the boiler, and is called a "dry" return. The advantage of a wet return is that it seals the drips from the risers, and prevents steam at a slightly higher pressure from entering the return main and branches, thus holding back the water from the more remote portions of the system. Although the entire system of pipes and radiators is supplied with steam from the same source, and therefore at the same original pressure, there is, as a matter of fact, a slight difference in pressure in different parts of the system. This is due, in part, to varying distances from the boiler, and in part, to more rapid condensation in some radiators than in others. Hence, if steam at boiler pressure is allowed to enter the return mains it is likely to prevent the water in certain branches from returning freely to the boiler. When the return mains are carried below the waterline of the boiler, each drip connection is sealed from the others, and any inequality in pressure will be balanced by the water standing at different levels in the different drip pipes. This will be more evident in a later diagram, and attention will be called to it again at the proper time. When it becomes necessary to carry the return pipes overhead, to clear doorways, or for any other reason, the effect of a sealed return may be secured by attaching a *siphon* to the bottom of the drip pipe, as shown at the right in Fig. 35. The water from the

drip falls into the loop formed by the siphon, and, after it is filled, overflows into the return main. Any difference in pressure between the drip pipe and return main is balanced by the water in the two legs of the siphon standing at different levels. In cases of this kind, it is not necessary to place siphons on the more remote drips, as the pressure is naturally lower at these points. This is illustrated in Fig. 35, where the drip at the extreme right is connected directly into the return main, while the next is provided with a siphon to prevent steam from being admitted and cutting off the flow of condensation toward the boiler.

The bottom of the siphon is usually formed by a back-outlet return bend, provided with a removable plug, so that any sediment which collects may be cleared out from time to time.

The supply mains are graded downward slightly, away from the boiler, and any condensation which forms in them is carried off by the drips at the bases of the risers. Gate valves are commonly placed

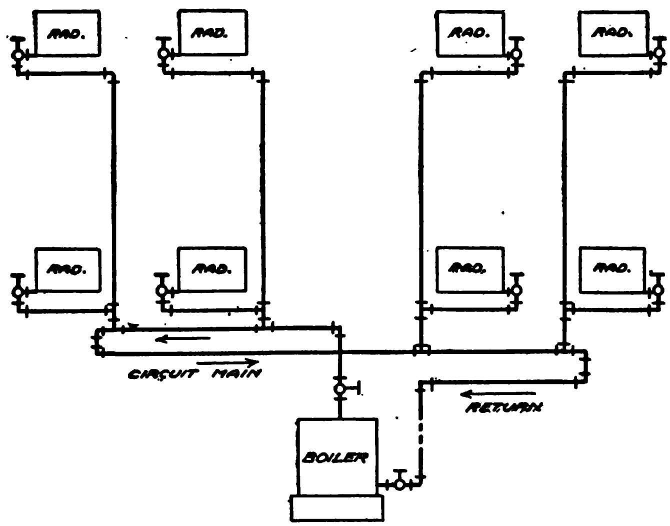


Fig. 36

in the supply mains and gate and check valves in the return; the latter being placed outside the stop valves.

Single Pipe Circuit System. This is similar to the single pipe relief system just described, except in the manner of running the basement mains (Fig. 36). In this case a single main of generous

size is carried entirely around the basement. Supply risers are taken from the top of this, and the condensation drains back into the same pipe and is carried along with the flow of steam to the extreme end, where it drains into a special return pipe, and is carried back to the boiler, as shown at the right. The connections between the risers and radiators are the same as in Fig. 35.

This system is adapted to buildings of small size, and especially those one and two stories in height. As the flow of steam and water is in the same direction, and as the pressure in the main drops slightly as the distance from the boiler increases, there is no danger of the condensation being held back. This system is less expensive to instal, as the return mains and drip connections are eliminated.

Overhead Single Pipe System. This arrangement is especially adapted to tall buildings, where the risers would have to be made

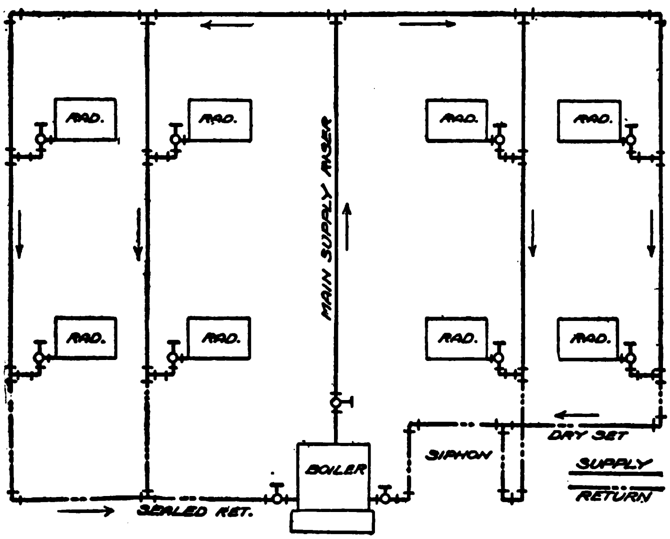


FIG. 37

excessively large if fed from the bottom. In this case the supply main is carried directly to the attic, where it branches to the various drops, which supply the radiators in the manner shown in Fig. 37. Here the steam and condensation flow in the same direction; hence the drops or "risers" can be made much smaller than with the

systems previously described. The radiator connections, and the method of caring for the return water, is practically the same as in Fig. 35. Although more frequently used in tall buildings, for the reason stated, it is also adapted to dwelling houses where it is desired to conceal the pipes or keep them as small as possible.

Two Pipe System. In this system steam is supplied at one end

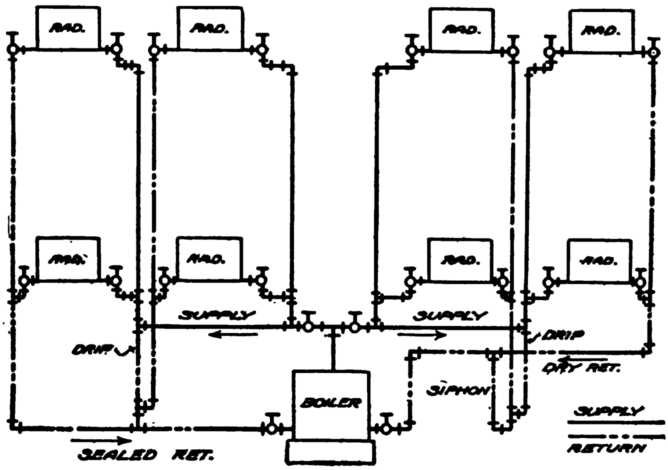


FIG. 38

of the radiator and the condensation removed from the other through separate connections, as illustrated in Fig. 38.

The steam mains are usually run near the basement ceiling and the radiators, supplied by means of an upward distribution.

The pipes in this arrangement may be of moderate size, because the condensation is carried away through a separate pipe, and therefore a higher velocity of steam can be allowed in the supply risers.

Both the sealed and dry returns are used with this system of piping, the former being preferable for reasons already given. It is evident from an inspection of the return connections at the left in Fig. 38 that no steam can get into the return mains, and that any difference in pressure in the various drip pipes will be balanced by the varying heights of the water columns within these pipes.

The radiators at the right are provided with an overhead or dry return, the drip at the end of the line on the right connecting directly with the return main, while the other two connect with a single siphon of the form indicated.

Choosing a System of Piping. No hard-and-fast rule can be laid down for the selection of a system of piping. The requirements of any particular case, together with the suggestions given in connection with the different systems, will usually be sufficient to enable one to make a choice. Sometimes a combination of two or more systems of piping is used in the same building, certain local conditions adapting one arrangement to one section, and another to some other part. This is very frequently done in buildings of large size.

Location of Risers. In general, all pipes should be run in such a manner as to be accessible for inspection and repairs. When it is not possible to do this, the pipes should be extra heavy and all joints thoroughly tested before closing in.

Concealed risers in partitions can sometimes be so made up so that by disconnecting at the top and bottom they may be withdrawn into the basement. A careful study of a set of plans will usually reveal locations for most of the risers in inconspicuous places, where they will be out of the way and still be accessible in case of repairs. Closets, back entries, corners of rooms behind doors which are usually open, and similar places should be made use of, so far as possible, when laying out a system of piping.

Locating Radiators. In locating the radiators three points should be kept in mind. In large rooms they should be placed in, or near, the colder parts, in order to distribute the heat as evenly as possible; this, however, is not of so much importance in rooms of small size.

The location of the furniture should be considered, and the radiators so placed as to interfere with it as little as possible. In deciding upon the location of a radiator the best position for the riser should also be taken into account.

It is hardly ever possible to so place the radiator as to fulfill all of these requirements to the best advantage, and it is usually necessary to make a compromise between them.

Radiator and Riser Connections. The method of making the connections between the supply mains and the risers, and between the risers and radiators, is a matter of much importance in the satisfactory working of a heating system. Fig. 39 shows an approved method of connecting a single-pipe first-floor radiator with a basement main.

The branch is taken off at an angle of 45 degrees, which allows the steam to enter from the top of the main while the condensation

flowing back from the radiator trickles down the side of the pipe to the bottom. When the connection is made with the top of the main, instead of as shown, the condensation drips across the center of the pipe instead of running down the side; and is therefore more likely

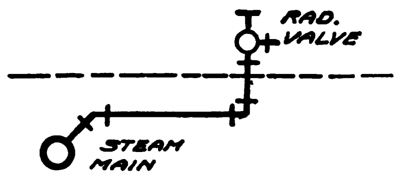


FIG. 39

to be carried back into the radiator with the inflowing steam. In making connections of this kind care must always be taken to give the pipe a good downward pitch from the base of the riser back toward the main. A union angle valve is best used in making the connection with the radiator, as it allows the condensation to drop into the vertical portion as soon as it passes through the valve.

About every third connection, or every second, if they are a considerable distance apart, should be taken from the bottom of the main as shown in Fig. 40, in order to drain off any condensation which may collect in it. Both the end of a main or branch and any low points in it should be dripped in a similar manner. This form of connection is applicable both to supply risers for the single-pipe and double-pipe systems of piping. If the main return is sealed the drip pipe may connect directly with it, as in Fig. 40, but, if it is overhead, a siphon loop should be provided at each drip, except at ends of the lines, as already stated.

If the building is not more than two stories in height the connections between the radiators can usually be made quite rigid if an expansion arm of 3 feet or so is provided between the main and the base of the riser. In high buildings, not exceeding eight stories in height, the riser is commonly anchored at the center and allowed to expand upward and downward from this point. In this arrangement the connections between the risers and radiators should be made as in Figs. 35 and 36, in order to give sufficient flexibility.

In tall office buildings slip joints, or offset loops, should be provided every six or seven stories. In the best class of work it is customary to place valves at the top and bottom of each riser supplying

two or more radiators, for shutting off in case of repairs, without interfering with the operation of the rest of the system.

Connections with Wall and Ceiling Coils. The methods of

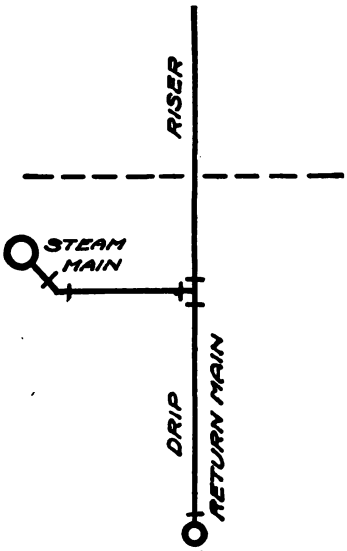


FIG. 40

making the supply and return connections for wall coils of different forms are shown in Figs. 11, 12, and 13.

In the case of overhead coils, the connections are made similar to those in Fig. 12, except the return should drop a few inches close to the coil before being carried over to the return riser.

Sometimes in schoolhouses the return from each coil is carried to the basement separately and connected with the main below the water line. This prevents steam from entering the return end of the coil and pocketing air in the center of it when first turned on.

Location of Air Valves. The air valves are commonly placed in the last section of cast-iron radiators, about half way down from the top. In the case of wall coils, like Figs. 11 and 12, they are placed in the header at the return end of the coil. In return-bend coils they are connected into the top of the return pipe just inside of the shut-off valve. When separate returns are carried from each coil to the basement the air valves are placed in the side of the pipe just below the basement ceiling.

Pipe Sleeves and Plates. Sleeves should always be provided where steam and return pipes pass through walls and floors. These should have a diameter from one-half to one inch greater than the pipe, according to its size. In the case of floors and wooden partitions the sleeves are made of galvanized iron securely fastened to the woodwork, and finished with metal floor, wall, or ceiling plates, as the case may be.

When the pipes pass through brick or cement walls the sleeves are usually made of wrought-iron pipe, one size larger than the pipes which are to pass through them.

Boiler Connections. The supply and return connections at the boiler will vary slightly, according to local conditions. In the simplest case, with a single boiler, the supply main is taken from the top, furnished with a stop valve, and then carried to the various branches as may be required. The main return is brought back, as most convenient, to a point near the boiler, where it is provided with a stop and check valve, the former being placed next to the boiler. Feed and draw-off connections are made with the openings provided for this purpose, which will vary somewhat with the type of boiler. When there are two boilers used the connections are more complicated, as shown in diagram in Fig. 41. In laying out the piping for two boilers the connections should be such that either boiler can be used alone, or both together, as may be desired.

In Fig. 41 steam-supply pipes are taken from each boiler and joined with a header or drum, from the center of which is taken the steam-supply main. Valves are placed in both boiler connections and in the main. The latter is often omitted, but in case of an accident when both boilers are running, steam can be shut off by a single valve, which is sometimes a matter of great importance, and for this reason its use is recommended in the best class of work. The equalizing pipe, connecting the rear of the boilers, is for maintaining the same pressure in each. In some cases the pressure will be equalized through the steam outlets, but this cannot be depended upon, and it is better to provide a special pipe for this purpose. If the pressure is not the same in both boilers the condensation will be returned to the one offering the least resistance, making it necessary to blow out the surplus water into the sewer, and to fill up the other with cold water, at more or less frequent intervals. This results in a considerable loss of heat and makes it necessary to watch the boilers constantly.

When the pressure in the two boilers is the same the condensation returns equally to both, and the water-line stands at the same level in each. Examining the piping at the rear of the boilers it is seen that the main return is furnished with check and stop valves outside the boiler connections, so that the return can be shut off with a single valve, the same as the steam. Placing the check as shown allows the

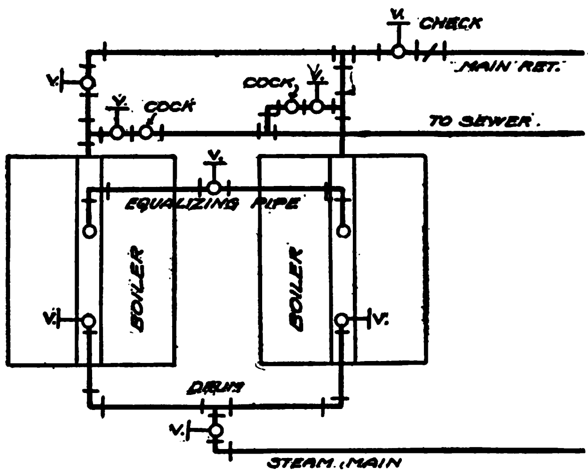


FIG. 41

return water to enter each boiler with equal freedom, which is not the case when separate checks are put in each connection.

A blow-off pipe to the sewer connects with each boiler, these pipes being provided with special blow-off valves, or ordinary gate valves and cocks.

Water Hammer. The object always in view, in laying out a system of piping, is to supply the radiators with steam, and return the condensation, without water hammer, or snapping in the pipes. The only way to avoid this is to keep the pipes free from an accumulation of water in any part of the system, as the noise is caused by the hot steam coming in contact with the cooler water and condensing suddenly.

This condition can be avoided by making both the steam and return pipes of ample size; grading the supply pipes so that the steam and water will flow in the same direction; avoiding pockets when

possible, and dripping those which cannot be avoided; using sealed returns when possible, and making dry returns of large size with a good pitch; placing siphons in the drip pipes, as already described.

It is often impossible to prevent more or less noise when steam is first turned into a system of cold pipes and radiators, owing to the excessive condensation; but after it is once warmed up and the pressure has become equalized no well-designed system of heating should give trouble from this cause.

Indirect Heating. This system of heating is sometimes used alone, but more frequently in connection with direct heating. For example, in dwelling houses it is often used for the more important rooms on the first floor, such as living rooms, dining-rooms, dens, etc., while the chambers, bathrooms, and upper hallways are provided with direct radiation. The best method of heating the sleeping rooms will depend somewhat upon personal taste.

The practice of sleeping with open windows is a common one at the present time, and, when this is done, direct heating is as good as indirect, and both cheaper to instal and to operate.

It is often a good plan to provide one sleeping room with indirect heat for use in case of sickness, as ventilation can be secured in this way without danger of cold drafts. In schoolhouses the class-rooms should always be provided with indirect heat for ventilating purposes, while direct coils or radiators may be placed in basement rooms, toilets, coat-rooms, and corridors.

Piping for Indirect Stacks. In a regular system of indirect heating the basement mains are run in practically the same manner as for the two-pipe system of direct radiation, shown in Fig. 38.

As the stacks are hung some 12 inches or so from the basement ceiling, the returns are usually carried near the floor, and the advantages of a sealed return apply here in the same manner as for direct heating. The water line in the boiler should, in general, be at least 18 inches below the bottom of the lowest stack, although if the stack is near the boiler where it receives the full pressure, the distance may, in special cases, be reduced to 12 inches. In large buildings, where stacks are located 100 feet or more from the boiler, the bottom of the sections should be from 24 to 30 inches above the water line, and the pipe sizes made such as to prevent any serious loss in pressure at the ends of the lines. It is often necessary in cases of this kind to place the boiler in a pit, in order to secure a proper elevation of

the stacks above it. A typical method of making the supply and return connections with an indirect stack is shown in Fig. 42. The end of the supply line is dripped outside of the valve, into the return,

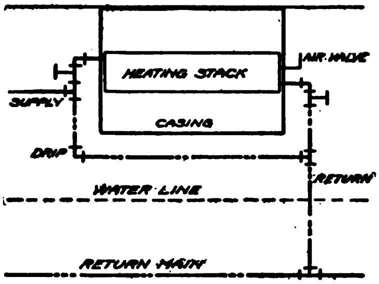


FIG. 42

so that any condensation which collects while the stack is shut off will be cared for. The return pipe connects directly with the main below the water line, thus preventing the entrance of steam to the return-end of the radiator. The air valve is connected into the end of the last section, above the return pipe, and is brought out through the casing so as to be easily reached for adjustment.

Stack Casings and Mixing Dampers. Fig. 43 is a section through a stack casing, showing a typical arrangement of air flues and

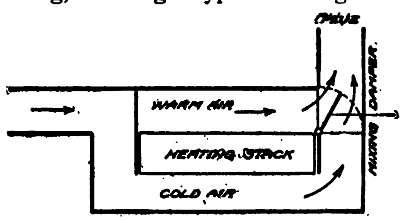


FIG. 43

mixing damper. The space above the heating stack should, if possible, be made 10 inches in height for dwelling-house work, and the space below 8 inches. If head room is limited, or the stack is small, these distances may be reduced to 8 and 6 inches respectively. In the case of heaters for school-rooms, where large volumes of air pass over them, the stacks are commonly supported in brick chambers with a space of at least 18 inches above them. The mixing damper, shown at the right in Fig. 43, is an arrangement for regulating the temperature of the air entering the room above. When in a horizontal position all of the air must pass through the heater, thus giving it the

highest possible temperature. When raised to a vertical position no air can enter from the space above the stack, and the only heat given to the air is that which it takes up in passing through the space beneath the sections and which is a comparatively small amount. By placing the damper in various intermediate positions any mixture of hot and cool air may be obtained to give the desired temperature to the room. Mixing dampers are commonly operated by means of chains carried up the warm-air flue to the room heated by the stack. The casings are usually of heavy galvanized iron put together with small bolts, so they may be easily removed for access to the heater sections in case of repairs.

Ducts and Flues for Dwellings. When the heaters are of small or medium size, as in the case of dwelling houses, the cold air is carried through shallow ducts connecting with the top of a basement window. The area of these supply ducts should be about 2 square inches for each square foot of heating surface in the stack. A wire screen should be placed over the outer end of the duct and a damper provided for regulating or shutting off the air supply. The warm air flues are commonly given an area of 2 square inches per square foot of heating surface for rooms on the first floor, and 1½ square inches for second and third-floor rooms. If vent flues are provided in rooms which have no fireplace they should be made practically the same size as the warm-air flues for first-floor rooms, and 30 per cent. larger for upper-floor rooms. In order to be effective flues of this kind should be carried up beside a warm chimney.

Flues for Schoolhouses. Both the supply and vent flues for first and second-floor standard class-rooms ($28' \times 32'$) are commonly given a sectional area of 6 square feet. In the case of third-floor rooms the supply flue may be reduced to 4½ square feet, while the vent is kept the same as for the first-floor rooms, or made slightly larger. In order to produce the necessary draft, the vent flues should be provided with aspirating coils containing about 30 square feet of heating surface per class-room. Cold-air inlet ducts should be made practically the same size as the corresponding warm-air flues, and both these and the vent flues should be provided with shut-off dampers. Mixing dampers of the general form shown in Fig. 43 should be furnished at the base of each warm-air uptake.

Pipe Sizes. The following tables give the sizes of both steam and return pipes for different locations, both for direct and indirect

radiation. They are based on the square feet of surface to be supplied, and may be safely used for lengths of run up to 200 feet, which will cover all ordinary cases of low-pressure steam heating. These tables are based on a condensation of ⅛ of a pound of steam per square foot of direct radiation per hour, and twice that amount for indirect surface.

Table VII gives the sizes of supply mains for direct radiation, and the corresponding sizes of sealed and dry returns to be used with them.

TABLE VII

Square feet of direct radiation	Size of supply pipe	Size of dry return pipe	Size of wet return pipe
30	¾″	¾″	¾″
60	1″	1″	¾″
120	1¼″	1″	1″
150	1½″	1¼″	1″
400	2″	1½″	1¼″
700	2½″	2″	1½″
1,100	3″	2½″	2″
1,700	3½″	2½″	2″
2,400	4″	3″	2½″
4,000	5″	3″	2½″
7,000	6″	3½″	3″
10,000	7″	3½″	3″
15,000	8″	4″	3½″

Table VIII gives sizes for circuit mains, as illustrated in Fig. 36.

TABLE VIII

Square feet of direct radiation	Size of circuit main
250	2″
400	2½″
700	3″
1,000	3½″
1,300	4″
2,200	5″
3,300	6″

Table IX gives the sizes of vertical supply risers and drops. The first column gives the square feet of radiation where the risers are fed at the bottom, and the steam and water flow in opposite directions. The third column is where the supply drops are fed at the top, and where both the steam and water flow in a downward direction.

TABLE IX

Up-feed, riser supplied at the bottom		Down-feed, riser or drop supplied at the top	
Square feet of direct radiation	Size of riser	Square feet of direct radiation	Size of drop
30	1″	60	1″
60	1¼″	100	1¼″
90	1½″	150	1½″
150	2″	300	2″
220	2½″	500	2½″
300	3″	800	3″

Table X is for indirect radiation, and is made up from Table VII by taking the radiating capacity of 1 square foot of indirect surface as equal to two of direct.

TABLE X

Square feet of indirect radiation	Size of supply pipe	Size of dry return pipe	Size of wet return pipe
15	¾″	¾″	¾″
30	1″	1″	¾″
60	1¼″	1″	1″
80	1½″	1¼″	1″
200	2″	1½″	1¼″
350	2½″	2″	1½″
550	3″	2½″	2″
850	3½″	2½″	2″
1,200	4″	3″	2½″
2,000	5″	3″	2½″
3,500	6″	3½″	3″
5,000	7″	3½″	3″
7,500	8″	4″	3½″

Heating Plans. In making a set of heating plans for a new building blue-prints are obtained from the architect, showing the various floor plans and basement.

One or more sections, or elevations, should also be included, from which to obtain the heights of the rooms and windows, and the space under the window sills. The former dimensions are to be used in computing the wall and window surfaces, and the latter in locating the radiators, as it is often desirable to place one beneath a window; hence the height of the available space must be known.

Tracings are then made of the floor plans, omitting architectural details and dimensions. All that is necessary being the walls, doors and windows, as shown in Figs. 44 to 51. Floor plans are usually drawn to a scale of 1/4 inch to the foot, except in the case of very

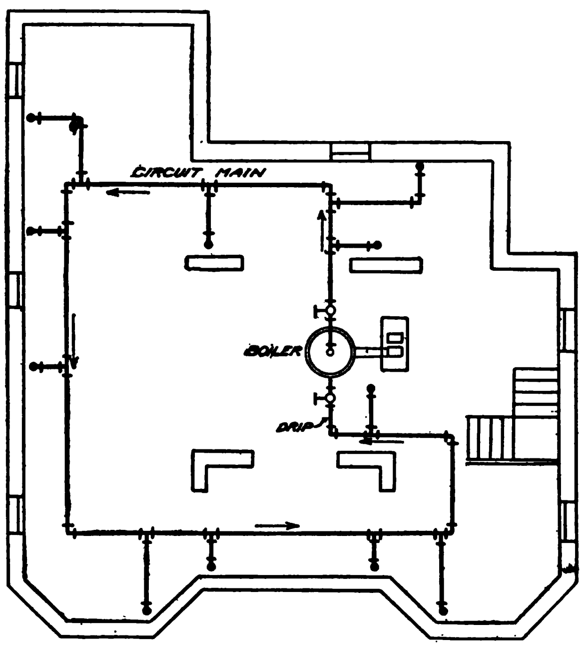


FIG. 44

large buildings, where they are made 1/8 inch to the foot. The next step is to measure up the wall and window dimensions with an architect's scale, and compute the square feet of radiation for each

room, making the various corrections for exposure, cold attics, etc., as described in Chapter IV.

Then locate the radiators in the different rooms, using a manufacturer's catalogue for determining the dimensions to give the re-

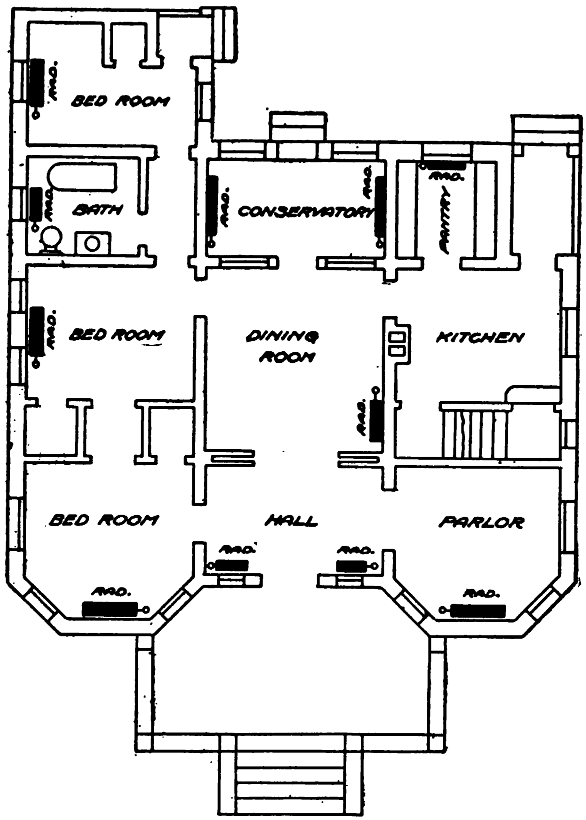


FIG. 45

quired heating surface. These should be drawn in to scale, to make sure there is ample room for the radiators and their connections. In general, not much less than 12 inches should be allowed between the end of a radiator and the corner of a room, if a valved connection is to be made. This space is more than is required by the valve, but allowance must be made for the manipulation of tools in making the connection. A single-pipe radiator, however, may be placed close to

the corner of a room if the valve connection is made at the opposite end. The supply and return risers are then drawn in, on the different floors, and their locations marked on the basement plan. The radiators are usually shaded or blacked over, when the drawing is

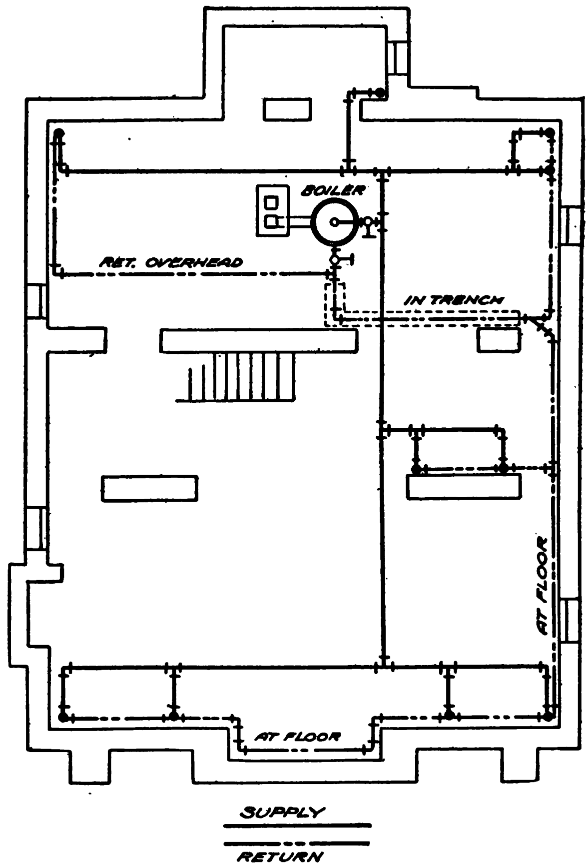


Fig. 46

inked in, as they show up much plainer in the blue-print if this is done. The top of a riser is usually shown by an open circle, but a section through a riser is shaded. This is shown in Figs. 47 and 48, where the second-floor risers are shaded on the first-floor plan and show as open circles on the second floor. The next step is to compute the size of boiler and locate it on the basement plan, and draw

in the steam and return connections between the boiler and the risers. In laying out the steam piping, care should be taken to make the runs as direct as possible and still allow sufficient flexibility for ex-

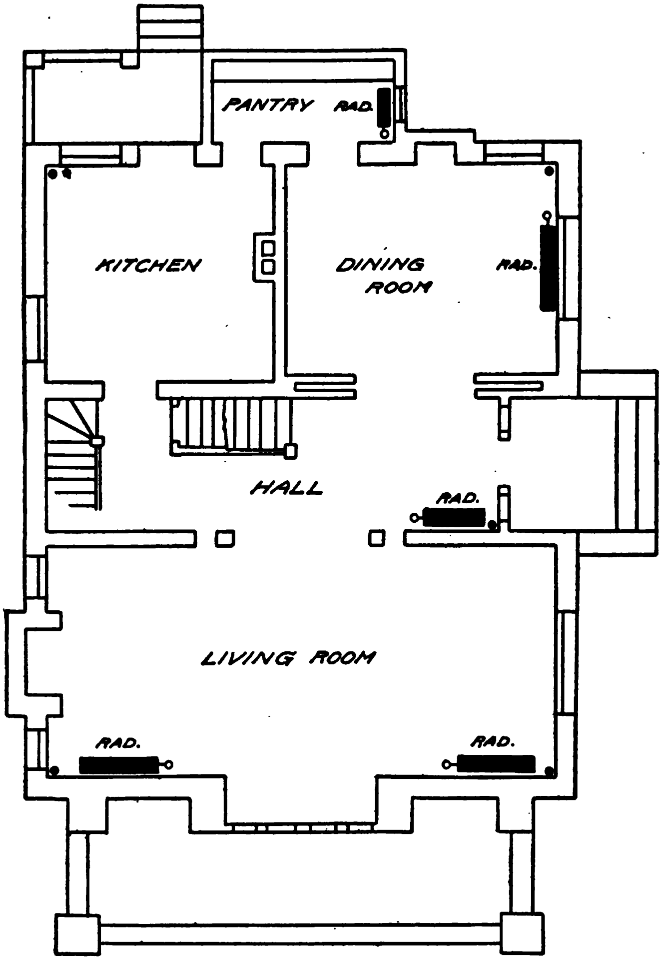


FIG. 47

pansion. The returns should be sealed, so far as possible, although it is often necessary to carry certain branches overhead to avoid doorways. The next and last step is to put on the dimensions and notes. If the radiators are all of the same height and pattern it is

only necessary to mark the square feet of heating surface on the plans, as a general description of other details of construction can be given in the specifications. If the heights or widths vary in different rooms, notes covering these details should be given on the plans.

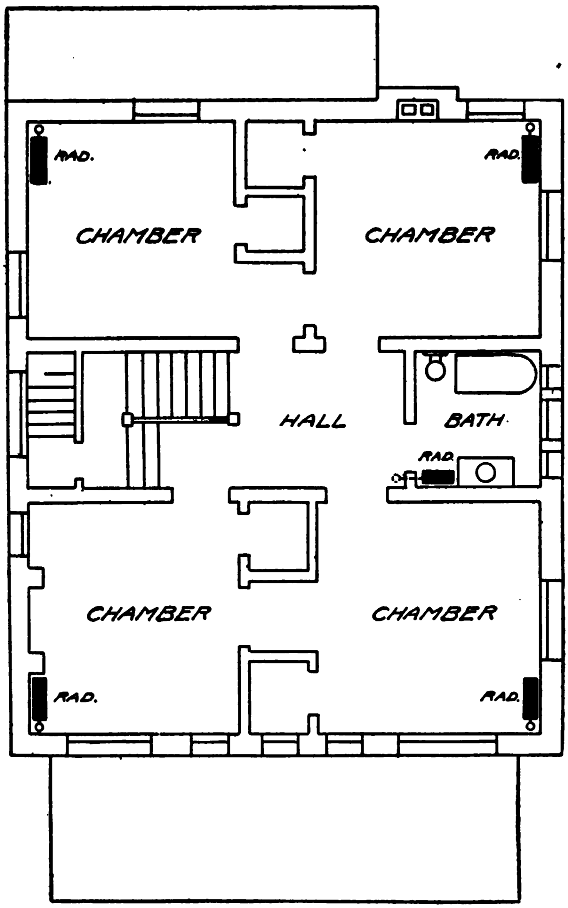


FIG. 48

The sizes of the risers may be denoted by marking on each plan the size where they pass through the floor.

Some engineers make a practice of drawing an elevation of each riser on the basement plan, starting from their true locations and extending them at an angle outside the building walls. Another

method is to number the risers on all the floor plans, and make a separate elevation of them on another sheet. These should be numbered to correspond with the plans, and the dimensions marked on

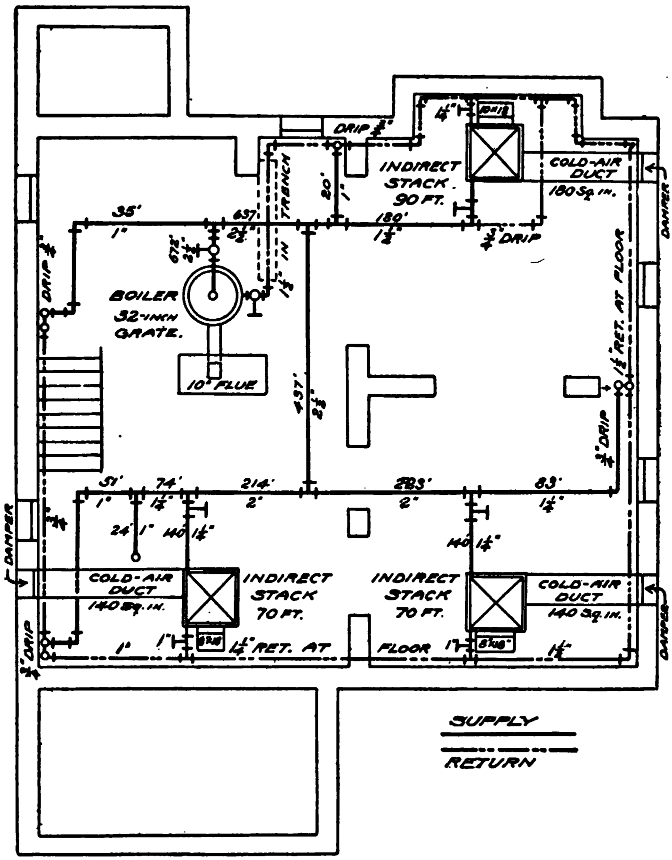


FIG. 49

them between each floor. This arrangement is to be preferred for large buildings.

In determining the steam-pipe sizes, first add up the square feet of radiating surface on each branch, putting down the sum on the plan in pencil, then by the use of the tables previously given mark the required size of each pipe at these various points. Next trace out

the returns and mark on the sizes, according to those of the corresponding steam pipes.

The location of all drips, siphons, or any special detail, should be clearly indicated on the drawings by means of notes.

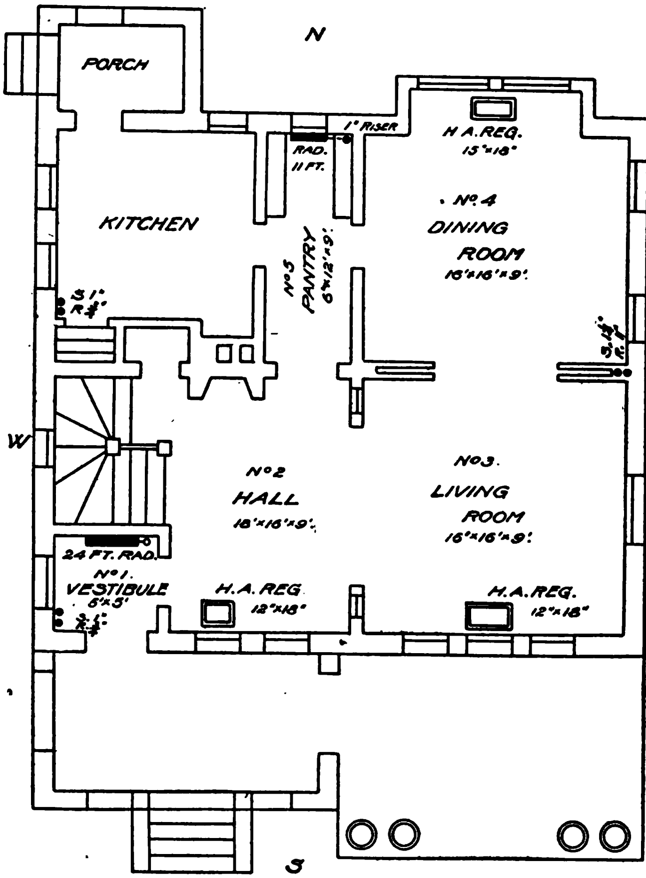


Fig. 50

After the plans have been completed in pencil they should be neatly inked in with lines of good width. Although a tracing may give a better appearance if made with light lines, the blue-print will show up much better if the lines are fairly heavy, especially those indicating the heating apparatus. Sometimes details of pipe connections are made much clearer by the use of simple marginal elevations. These

are not necessarily drawn accurately to scale, as they are used simply to show the *methods* employed, rather than actual sizes. In the case of indirect heating plans it is well to tint the edges of air ducts and stacks with a colored pencil. If yellow is used for this purpose it will

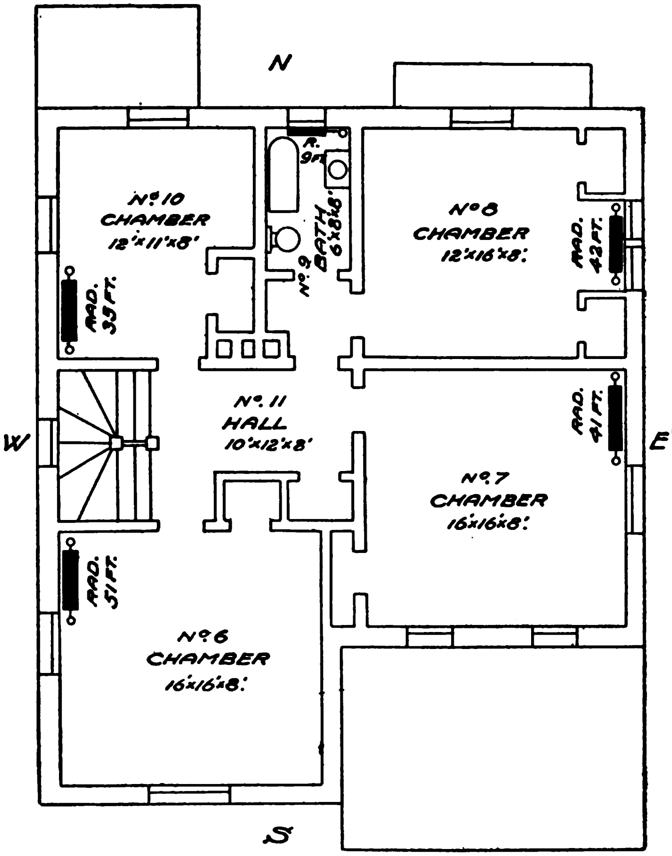


Fig. 51

come out quite clearly in the prints, and is a great assistance to the workmen in tracing out the various ducts and flues. In the case of large and complicated plants it is necessary to make many detail drawings in order to indicate clearly to the workmen just what is needed. The best method of doing this can only be learned by actual experience.

After one becomes somewhat familiar with designing, the tracings from the architect's plans can generally be made in ink at once, leaving in pencil such parts as are likely to be changed in making the finished drawing. This will save considerable work, and an ink tracing is much easier to work on when laying out a heating system than one done in pencil. Figs. 44 and 45 show the basement and first-floor plan of a bungalow heated by direct radiators supplied from a one-pipe circuit system. The method of drawing in the radiators and indicating their connections, is shown in Fig. 45. On the basement plan the method of indicating a round cast-iron boiler is given, also the way of showing the pipe and fittings and valves.

The direction of flow of the steam and condensation is indicated by arrows.

A careful inspection of the piping will show it to be flexible under expansion, sufficient spring being provided by the run-outs to the bases of the risers.

This makes an especially good arrangement for a one-story bungalow on account of its simplicity. Figs. 46, 47 and 48 show the basement and floor plans of a two-story house heated by direct radiation on a one-pipe relief system of piping. It will be noted that the risers to the second floor are carried up in the corners of rooms where they will show as little as possible. Offsets, and connections between risers and radiators are commonly made in the floor space, and are not shown on the plans unless there is something special which should be indicated. Attention is called here to the method of distinguishing between steam and return pipes, the former being shown by full lines and the latter by two dots and a dash. Here, again, the flexibility of the piping should be noted. The returns are in greater part carried along the outer walls, with one branch overhead and a portion of the main return next to the boiler in a trench. In this layout the pantry radiator is drained back into the steam main, while all other risers have a separate drip connection with the return. The plans just shown have no dimensions upon them, and are given for the purpose of illustrating the method of showing the different parts of a simple heating system without complicating it with notes and dimensions.

A Problem in Design. Having considered the methods for computing the sizes of different parts of a heating system, their applica-

tion to the actual design of a combined direct and indirect steam plant will now be taken up.

Let the problem be to make the heating plans for an eight-room house as illustrated in Figs. 49, 50, and 51. The dining-room, living room, lower and upper halls, are to be heated by indirect stacks placed in the basement. The heat for both halls is to be supplied through a single register on the first floor, the upper hall getting its heat from the warm air passing up the open stairway. The front vestibule and pantry on the first floor, four chambers and bathroom on the second floor are to be heated by direct radiation. The building faces the south, and is of first-class construction. Although the attic is unwarmed, it is not necessary to provide additional radiation in the upper rooms on this account, as the warm air rising from the rooms below is sufficient to offset this.

The first step is to number the rooms to be heated, and measure up the net wall and window surface, which is found to be as follows:

First Floor	*Net Wall*	*Glass*
Room No. 1	50 sq. ft.	40 sq. ft.
" " 2	138 " "	45 " "
" " 3	223 " "	65 " "
" " 4	208 " "	80 " "
" " 5	44 " "	10 " "
Second Floor		
Room No. 6	286 " "	50 " "
" " 7	203 " "	55 " "
" " 8	174 " "	50 " "
" " 9	38 " "	10 " "
" " 10	144 " "	40 " "
" " 11	65 " "	15 " "

Next determine the direct radiating surface for a southern exposure by dividing wall and glass surfaces by 10 and 3, respectively, and adding the results. In making these computations it is customary to consider all fractions over 0.2 as a whole number. That is, 10.3 square feet of radiation would be called 11 square feet, and so on.

First Floor	*Direct Radiation*
Room No. 1	18 sq. ft.
" " 2	29 " "
" " 3	45 " "
" " 4	48 " "
" " 5	8 " "
Second Floor	
Room No. 6	46 " "
" " 7	39 " "
" " 8	35 " "
" " 9	7 " "
" " 10	28 " "
" " 11	12 " "

Corrections should now be made for exposure; and those radiators which are to be of the indirect form should be multiplied by 1.5. Where a room has two exposures as N.W., the average of the correction factors for N. and S. should be used.

First Floor	*Exposure*	*Factor*	*Direct Surf.*	*Indirect Surf.*
Room No. 1	S.W.	1.10	24 sq. ft.	
" " 2	S.W.	1.10		48 sq. ft.
" " 3	S.E.	1.05		72 " "
" " 4	N.E.	1.20		87 " "
" " 5	N.	1.30	11 " "	
Second Floor				
Room No. 6	S.W.	1.10	51 " "	
" " 7	S.E.	1.10	41 " "	
" " 8	N.E.	1.20	42 " "	
" " 9	N.	1.30	9 " "	
" " 10	N.W.	1.25	35 " "	
" " 11	W.	1.20		23 " "

In computing the size of radiator for the front vestibule (room No. 1), the outside door is figured the same as a window, and the radiating surface multiplied by 1.2 to offset the effect of inleakage of cold air around the door.

The square feet of direct radiation, in next to the last column, is obtained by multiplying the radiating surfaces for a southern exposure, as previously found, by the corresponding factors for the

actual exposure. For example, the square feet of radiation first computed for room No. 6 is 46, and this corrected for exposure is $46 \times 1.10 = 51$ square feet, the amount shown on the plans (Fig. 51).

The amount of indirect radiation for rooms Nos. 2, 3, 4, and 11 is found by correcting for exposure, in the manner described above, and then multiplying by 1.5. The direct radiators are now drawn in, the two-pipe system being used, except for the bathroom, pantry, and vestibule, which have one-pipe radiators. The risers are next located, and carried to the basement plan. The radiators in chambers No. 7 and No. 8 are connected with the same supply and return risers, which are carried up through the first story in the partition near the folding doors between the living room and dining-room.

The three warm-air registers are now located, and the indirect stacks drawn in beneath them on the basement plan (Fig. 49).

The sections of indirect radiators used for dwelling-house work usually contain 10 square feet of heating surface each; hence the surface contained in each stack must be a multiple of 10. On this account the heater for room No. 3 contains 70 square feet of surface instead of 72, as computed, and the heater for room No. 4 contains 90 square feet instead of 87 for the same reason. As the lower and upper halls are heated from the same stack, the radiating surfaces computed for rooms No. 2 and No. 11 are added together, and a multiple of 10 used, which calls for 70 square feet of heating surface. The cold-air supply ducts to the indirect stacks are computed on a basis of 2 square inches of area for each square foot of heating surface in the stack, and the warm-air flues to the first floor given made the same area. The registers are made 50 per cent. larger than the warm-air flues connecting with them, to offset the effect of the grille work over the opening. The supply and return piping is then laid out as shown, the latter being carried along the outer walls and below the water line. The square feet of direct heating surface on each branch is added up and marked on the plan as shown, indirect surface being taken as twice the amount of direct. The corresponding pipe sizes are now taken from Table VII and placed directly below the square feet of radiation they are to supply. Ordinarily, the latter figures are put down in pencil and then erased after the pipe sizes have been inked in, although in large plants it is a good idea to mark them in lightly with red ink, for possible future reference. It will be noticed that the steam connections to the indirect

stacks are one size smaller than called for in Table VII. This is because the surface only exceeds the limit by a small amount, and the pipe lengths are very short.

The next step is to compute the square feet of grate surface in the boiler.

The equivalent square feet of direct radiation in the building is 672, and this multiplied by 250 calls for $672 \times 250 = 168{,}000$ *TU* per hour to be supplied by the boiler. Looking in Table III it is found that a Class B boiler will supply 32,000 *TU* per hour per square foot of grate. Therefore, $168{,}000 \div 32{,}000 = 5\frac{1}{4}$ square feet of grate area are required, which is practically a 32-inch round grate. Assuming a height of approximately 40 feet from the level of the grate to the top of the chimney, it is found from Table V that a 10-inch flue is required.

Specifications. The specifications for a plant of this kind should give a brief description of the material to be used, including all necessary information not shown on the plans, and should cover such items as boiler and trimmings; smoke pipe; feed and blow-off connections; pipe and fittings; valves; insulation; radiation; painting and bronzing; galvanized iron work, including cold-air ducts, dampers, stack casings, warm-air flues and registers. To this should be added any special information or directions which seemed to be called for by the work under consideration.

TEST QUESTIONS:

(1) Define a low-pressure steam-heating system. Into what two divisions is it divided?

(2) What is the distinguishing feature of a single-pipe system of piping?

(3) What is the difference between a sealed and a dry return? Which gives the best results?

(4) What is a siphon loop, and where used?

(5) What is a single-pipe circuit system of piping, and to what kind of houses is it adapted?

(6) How does the two-pipe system of piping differ from the single pipe?

(7) What are the advantages of the overhead system of piping?

(8) Are concealed pipes and risers advisable?

(9) What three points are to be considered in locating direct radiators?

(10) Draw a diagram showing two methods of making the connections between a supply main and the base of a riser. State when each should be used.

(11) What provision should be made for the expansion of risers in tall buildings?

(12) Where should the air valve be placed on a direct cast-iron radiator?

(13) What is a pipe sleeve, and where used?

(14) What is the purpose of an equalizing pipe when two boilers are connected in a battery?

(15) What is the cause of water hammer? State five precautions to be taken in laying out a system of piping to prevent it.

(16) What rooms in a dwelling house are commonly heated by the indirect system?

(17) What should be the least vertical distance between the bottom of the lowest heating stack and the water line in the boiler, under ordinary conditions?

(18) Draw a diagram showing a typical method of making the steam and return connections with an indirect stack.

(19) What height of space is usually allowed between the top of the stack and the casing, in dwelling-house work? In schoolhouse work?

(20) How is the size of a warm-air flue computed for a first-floor room in a dwelling house?

(21) What sizes of supply and vent flues are used for a standard-sized class-room on the first floor? On the third floor?

(22) Explain the operation of a mixing damper.

(23) What is the first step in making a set of heating plans? What scale is commonly used for the floor plans?

(24) How are radiators usually shown? What dimensions are commonly marked on the plan?

(25) How are supply and return risers usually indicated on the different floors?

(26) What is the method of determining the pipe sizes from the tables and marking them on the drawings?

(27) What parts of an indirect-heating plan should be tinted? Why?

CHAPTER VII

Exhaust-Steam Heating

The term exhaust-steam heating, as used in the present instance, refers to all cases where the exhaust from engines or pumps is utilized in a heating system, under a pressure at, or slightly above, that of the atmosphere.

Exhaust steam is also used extensively in connection with vacuum heating, but as it differs in no way from live steam when used in this manner, only the pressure system will be considered in the present chapter.

After the exhaust enters the heating system its action is no different from that of live steam taken from the boilers, and the piping and radiators differ in no way from the ordinary systems of low-pressure heating already described.

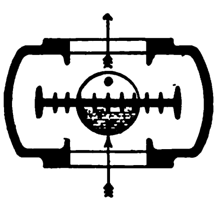
The difference in equipment consists in the additional apparatus necessary for removing the oil from the exhaust; means for reducing live steam from boiler pressure to a point suitable for heating; and an arrangement for returning the condensation from the heating system back to the boilers against a higher pressure.

Before taking up the design of exhaust systems the different pieces of apparatus employed will be briefly described in order that their use and operation may be clearly understood.

Oil Separator. The oil is removed from exhaust steam by passing it through a device called a *separator* or *extractor*. These vary widely in form and construction, but may be roughly divided into two classes known as "baffle plate" and "centrifugal" separators. A common design of the former is shown in Fig. 52. This consists of a cast-iron chamber "a" connecting with a receiver "b" below it. The chamber "a," which is connected into the line of exhaust piping, contains a baffle plate extending across the central portion, but having ports at each side, the combined areas of which are equal to, or slightly in excess of, that of the exhaust pipe. The position of the baffle plate and ports, with reference to the inlet and outlet openings, is best shown in Fig. 53, which is a horizontal section through the chamber "a."

Steam entering at a high velocity strikes the baffle and is deflected around it in order to pass through the ports. This sudden reduction in velocity, and change in direction, causes the heavier particles of

FIG. 52



SECTIONAL PLAN

FIG. 53

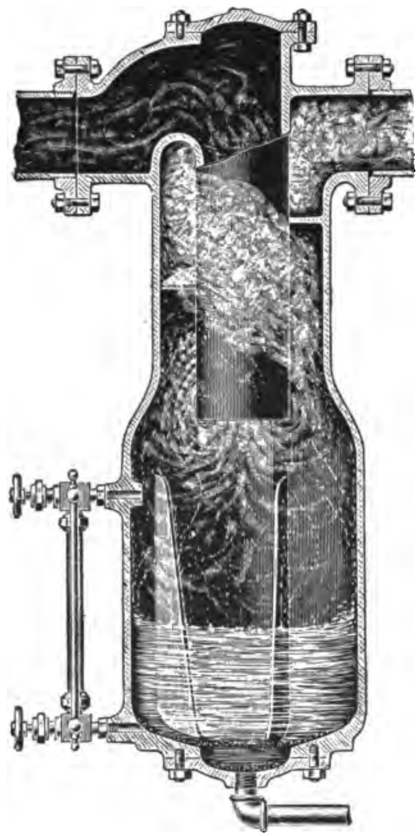


FIG. 54

oil and water to become separated from the steam, and fall to the receiver "b," from which the mixture is drained to the sewer.

In the centrifugal form, the steam is given a rotary or whirling motion as it enters the body of the separator. This tends to throw the heavier particles toward the outer side of the chamber by the action of centrifugal force, where they collect on the inner surface of the shell and fall to the receiver below, as in Fig. 54. The action of this type of separator is sometimes increased by short projections

or blades upon the surface of the chamber, which serve to catch the oil as it is thrown outward by the centrifugal action.

In other forms the oil is removed by passing through an open filter of excelsior or coke, which must be removed from time to time, as it becomes saturated with oil.

Back-Pressure Valve. A back-pressure valve is a form of relief or safety valve of large size, placed in the outboard branch of the exhaust pipe. Its office is to prevent the back pressure on the engines from rising above a certain fixed point, thus reducing the power developed under normal conditions.

Such action is liable to take place when the amount of exhaust equals or slightly exceeds that required by the heating system. By placing a back-pressure valve in the outboard branch, and setting

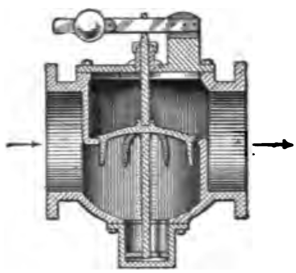


FIG. 55

it to open at some fixed pressure, usually from 1 to 5 pounds, any surplus steam above that condensed in the heating system will pass outboard automatically, without raising the pressure above the point for which it is set. A common form of back-pressure valve is shown in Fig. 55, the path of the steam being indicated by the arrows. The valve is held in place by a weighted lever, as shown, the weight being adjustable for different pressures. When the pressure inside the chamber reaches the point for which it is set, the valve is raised from its seat and the surplus steam passes outboard as indicated.

The piston or dash-pot, at the bottom, steadies the valve and prevents chattering or vibration. Back-pressure valves are made in many different forms, both for vertical and horizontal pipes, and form an important part of every exhaust-heating system.

Exhaust Head. An exhaust head is a form of separator, placed at the top of an outboard exhaust pipe, for removing the moisture

carried up with the steam and preventing any spray from falling on roofs and sidewalks below. Exhaust heads are similar in construction to simple separators, and are drained back to the blow-off tank or sump well.

Pressure Reducing Valve. A pressure-reducing valve is a device for reducing the pressure of a gas or liquid from a higher to a lower pressure. In exhaust-heating plants it often happens that there is not sufficient exhaust steam available for doing the entire work. In cases of this kind it is necessary to admit enough live steam from the boilers to make up the deficiency. As the boiler pressure in a

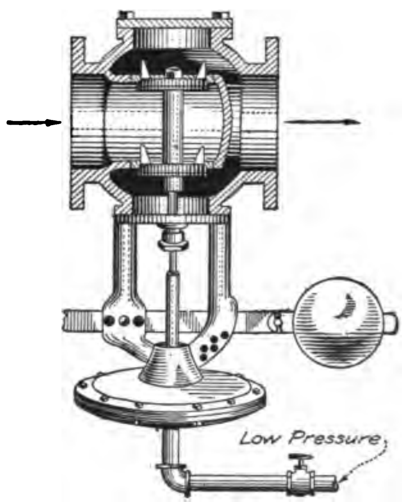


FIG. 56

power plant is always much higher than that carried in the heating system, the steam is passed through a *reducing valve,* so called, before being admitted to the heating main. Fig. 56 shows a form of reducing valve especially adapted to this purpose.

The main chamber contains a balanced double-ported valve, held in a closed position by a diaphragm connected with the low-pressure system, by means of a small pipe, as shown. The adjustment is made by shifting a weight upon a lever which tends to open the valve. When the pressure on the low-pressure side drops below the point for which it is set, the valve opens automatically, and admits more steam, as may be required. When the pressure exceeds the normal,

the valve closes in a similar manner, and shuts off the live-steam supply. Under ordinary working conditions the valve assumes such a position that the opening is just sufficient to maintain the desired lower pressure, and any slight fluctuation is provided for by a corresponding movement of the valve. Some reducing valves are operated entirely by springs, others by a combination of springs and pistons, and others by springs and diaphragms. The combination of a reducing valve and a back-pressure valve serves to automatically maintain a constant pressure in a heating system supplied with both exhaust and live steam. A reducing valve when connected with a system of piping should always be provided with a valved by-pass, and cut-out valves,

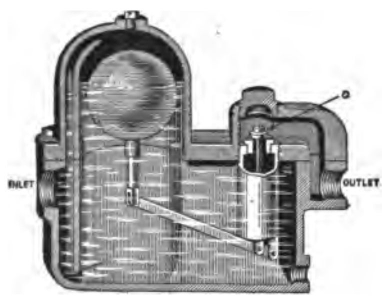


FIG. 57

for use in case of repairs. By closing the cut-out valves and opening the by-pass valve slightly, the pressure in the heating system can be regulated by hand for a limited period, while repairs are being made to the reducing valve.

In order to set and regulate the valve, a small pressure gauge should be connected into the piping on the low-pressure side, in such a position that it can easily be read while manipulating the valve.

Steam Trap. A steam trap is an arrangement for discharging the water of condensation from any part of a system of piping without allowing the passage of steam with it.

There are many forms of traps operating on different principles, a familiar type being shown in Fig. 57. This is known as a float trap, and its operation is as follows: Water enters at the left as indicated, filling the trap to such a point that the rising of the float opens the small valve "a" and allows the water to pass out until the float falls sufficiently to close the valve. As the bottom of the sleeve surround-

ing the valve is never uncovered before the falling of the float closes the valve, it is impossible for any steam to pass through the trap. In the bucket-trap, so called, the float is replaced by an open bucket somewhat smaller than the interior of the trap. Water entering the trap first floats the bucket, then overflows into it until it becomes sufficiently heavy to sink to the bottom of the trap. This action opens a valve and allows a portion of the water to be discharged through an opening inside the bucket near the bottom. Before the water is sufficiently lowered to uncover the opening the bucket is lightened and rises, thus closing the valve. Other traps operate on the expansion principle the same as an automatic air valve; the valve remaining open when covered with water, but closing from the expansion of a series of metal rods, or from the vaporization of a volatile liquid when in the presence of steam. Traps are used for draining the condensation from the low points in steam mains, and for discharging the return water from entire heating systems into vented tanks or receivers, for pumping back to the boilers. They should, in general, be provided with cut-out and by-pass valves, the same as described for pressure-reducing valves, and for the same reasons.

Return Trap. The traps just described can only discharge against an equal or lower pressure, being commonly used under the latter condition. When it is desired to force the water against a higher pressure, as in returning the condensation from a low-pressure heating system to a high-pressure boiler, a *return* trap is used.

There are several forms of this device, but all work on practically the same principle, which is illustrated by the diagram shown in Fig. 58. In this arrangement, "A" is the trap body or chamber; "B" the inlet from the receiver; "C" the outlet from the trap connecting with the boiler, below the water line, and "D" a pipe connecting the steam space of the boiler with the top of the trap. The operation is as follows:

Water enters the trap through the pipe "B," until the float "F" is raised sufficiently to open the valve "E" and admit steam at boiler pressure to the top of the trap through the pipe "D." The trap being under the same pressure as the boiler, and at a higher elevation, the water flows into the boiler by gravity through the pipe "C." High-pressure steam is kept from backing into the heating system by the check valve in the pipe "B." When the water

level in the trap drops to a certain point the valve "E" closes, and the steam contained in the top of the trap condenses, thus forming a vacuum which draws up the water from the receiver. During this process, water from the boiler is prevented from backing into the trap by the check in pipe "C." After sufficient water has entered the trap, the float rises and opens the valve "E," and the operation is repeated. In actual construction the trap is provided with a

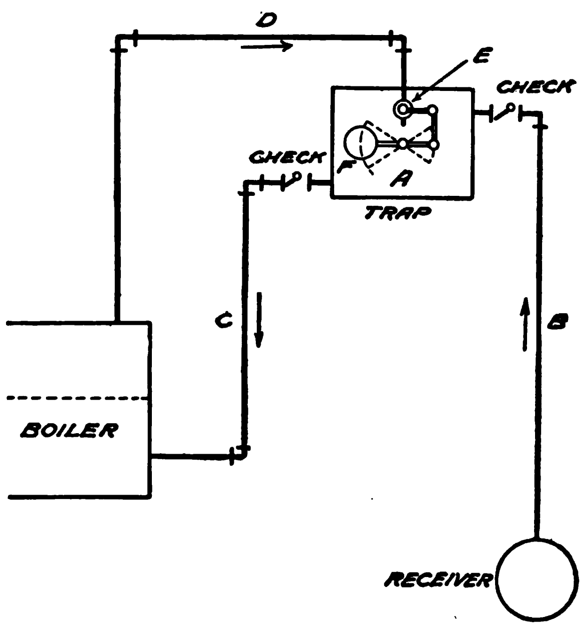


FIG. 58

system of levers and weights, which causes the valve to open suddenly when the trap becomes filled, and to close in the same manner when nearly empty. In order to work satisfactorily the trap should be placed at least 2 feet above the water line of the boiler.

The various return pipes are connected with the receiver, which should be low enough to allow the condensation from the various lines to flow into it by gravity. Return traps are commonly used

instead of pumps for returning the condensation to high-pressure boilers in small plants.

Steam Pumps. In the equipment of larger plants it is more common to use direct-acting steam pumps for this purpose. These are usually of the duplex pattern, having two steam cylinders and two water cylinders, side by side. The pump is usually connected with a return tank or receiver, as shown in Fig. 59, and arranged to work automatically by changes in the water level in the tank. This result is accomplished by placing a copper float in the tank and attaching it by means of levers with a balanced valve "A," in the steam pipe,

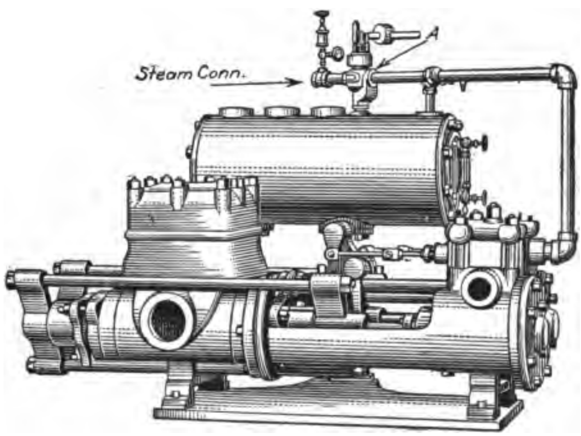


FIG. 59

as shown in the cut. The tank is usually vented to the atmosphere, and the returns from the heating system trapped into it. When the water reaches a certain level, near the center of the tank, the float rises sufficiently to open the steam valve "A" and start the pump, thus returning the water to the boiler. As the water level drops the valve closes, and the pump stops until the tank again fills up to the proper point for starting it. In very large plants two pumps are used instead of one, as shown in Fig. 59. In cases of this kind each pump is made of sufficient size to do the whole work, which leaves a reserve pump in case of a breakdown. When this

is done the receiving tank is commonly made of boiler plate instead of cast iron, and placed between, and slightly above, the pumps.

The same arrangement of float and valve is used as before, the latter being placed in the main steam pipe before it branches to the two pumps. Valves should be placed in all pump connections, both for steam and water, so that either can be cut out when not in use. The use of a receiving tank is to furnish a sort of reservoir or overflow in case a large amount of condensation is suddenly discharged by the traps, as in the morning when steam is first turned into the cold pipes and radiators. Another reason for using a tank is to provide a vented space into which the various traps may discharge,

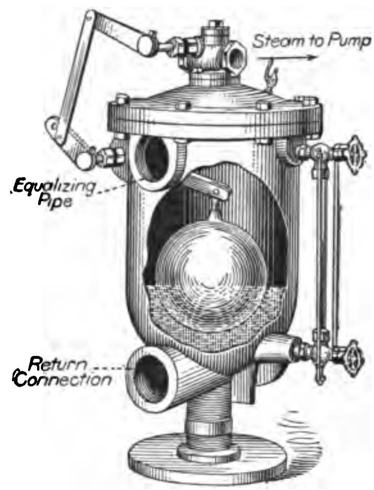


Fig. 60

especially if some of them are used for draining high-pressure apparatus.

It frequently happens that a trap in discharging allows a small quantity of steam to pass; also water discharged from a high pressure into a lower usually breaks into steam. For this reason, when several traps under different pressures discharge into a sealed return, there is apt to be more or less snapping and water hammer, which may be avoided if a vented receiver is used and the connections from the traps are made above the water line.

When the pump is used simply to return the condensation from a

low-pressure heating system, and where there are no high-pressure drips to be cared for, the receiver is often omitted and the main return pipe connected directly with the suction of the pump, without the use of a trap.

The automatic operation of the pump is secured in this case by a device called a pump *governor*, and shown in Fig. 60. This consists of a cast-iron chamber, containing a float, attached by means of levers with a balanced steam valve the same as in the regular form of combined pump and receiver. It is often desirable to seal the main return, the same as in gravity heating, and this may be done by placing the pump governor at the desired elevation, and connecting the lower opening with the return main and the upper one with an equalizing pipe carried to the low-pressure supply main. The high-pressure steam connection with the pump is attached to the balanced valve at the top of the governor. The operation of this device is practically the same as that already described in connection with the combined pump and receiver. Fresh water may be fed to the boilers by admitting it to the receiving tank, or directly into the return main, near the pumps, when no receiver is used. Return pumps are rated both on a boiler horse-power basis, and also on the square feet of direct radiation which they will care for. When using catalogue ratings it is generally more satisfactory to select an outfit having a capacity nearly double that given, and operate the pump at a slower speed.

Feed-Water Heater. Feed-water heaters are generally installed in connection with an exhaust heating plant.

About ⅙ of the steam generated by a boiler plant may be used in the form of exhaust from the engines for heating the fresh feed water. When all of the exhaust steam is condensed in a heating system and returned to the boilers, a feed-water heater is of but little benefit, as the amount of fresh water supplied is very small, and can be introduced with the return from the heating system. During the summer months, however, while the heating system is out of use, and in cases where only a part of the exhaust steam can be used for warming, a feed-water heater results in a constant saving of fuel and should always be employed. There are two general types of heaters in use, known as open and closed heaters. In the former the cold water is mixed directly with the steam and condenses it by actual contact, while in the latter the water to be heated passes through brass or copper tubes surrounded by steam. A common form of

closed heater is shown in section in Fig. 61. The feed water from the pump enters the bottom as indicated by the arrow, and is spread out by a curved deflector of such form that it tends to throw any solid matter to the bottom of the chamber, where it can be blown off from time to time as it collects. After passing upward through the tubes it enters the feed pipe again and is discharged into the

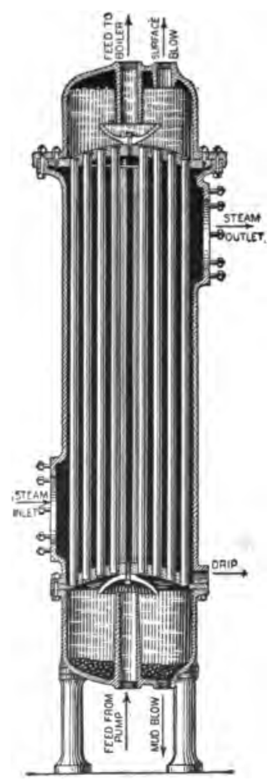


FIG. 61

boiler. Any scum which rises to the top of the water may be removed by the surface blow-off.

Exhaust steam enters the heater near the bottom of the shell and passes out near the top on the opposite side, as indicated by the arrows. Heaters of this type are made in both vertical and horizontal patterns in many sizes, and are commonly rated according to

the horse power of the boilers which they will supply, it being customary to allow ⅛ of a square foot of tube surface per horse power.

Fig. 62 shows a form of open heater quite frequently used in exhaust-heating plants. This is a combination of oil separator and trap, feed-water heater, automatic-return tank, and filter. The exhaust steam enters at the right, and after passing through the oil separator

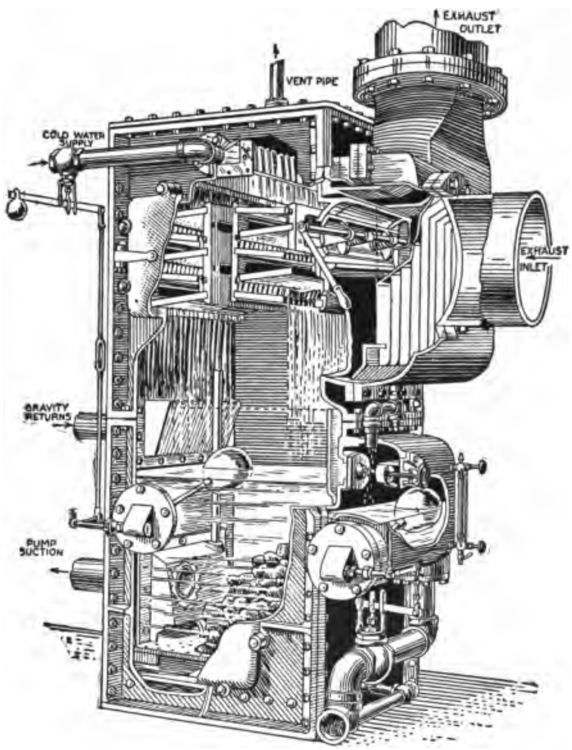


FIG. 62

a portion is deflected into the heater, where it meets the small streams of water falling over the trays. The oil removed from the steam falls into a trap beneath, and is discharged into the sewer. Cold water is admitted automatically by means of a float connected with a balanced valve located near the upper left-hand corner of the cut. The edges of the trays are notched so that the water falls from one to another in the form of small streams, thus mixing more intimately

with the entering steam. The condensation from the heating system may be returned to the receiving tank at the bottom of the heater, either by gravity or trap, as called for by local conditions. Before entering the suction pipe to the pump the water passes through a filter of coke, for removing any oil which may still be present.

Pipe Connections. The method of connecting the various pieces of apparatus just described into an exhaust-heating system is shown in diagram in Fig. 63. The main exhaust from the engines enters beneath the floor, at the left, and is dripped where it rises to the floor above, through a trap, discharging into the main drain pipe; the trap being provided with cut-out valves and by-pass, as shown.

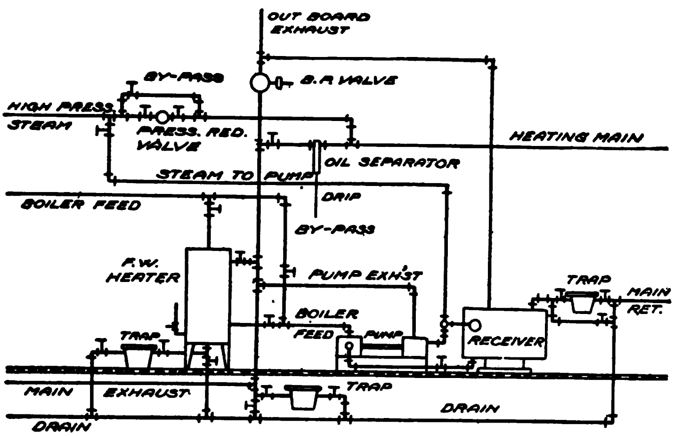


FIG. 63

The feed-water heater in this case has only one connection with the exhaust main, and is what is commonly known as an induction heater, steam being drawn into it by the slight drop in pressure due to condensation within. The surplus of steam which passes by the heater enters the heating main at the right through an oil separator.

The outboard exhaust pipe is provided with a back-pressure valve for relieving the pressure at any time the exhaust exceeds that which can be condensed in the heating system. Live steam is admitted, when needed, through a pressure-reducing valve, provided with a by-pass and cut-out valves. A high-pressure connection with the automatic-return tank and feed pump is made as shown, and the ex-

haust from the pump is connected into the main exhaust riser near the heater.

The main return from the heating system is trapped into the receiver at the right, and from here is pumped into the boilers through the feed-water heater, a by-pass being provided for use when the heater is cut out for repairs.

The drip from both the oil separator and heater is trapped to the sewer, by-passes being provided in each case. The exact method of making the steam and return connections for an exhaust-heating system will vary in different cases, but the general principles to be followed will be practically the same in each. Exhaust heating is largely used in office buildings, and institutions having their own power plant. Any of the systems of piping described in Chapter VI may be used, although the overhead distribution shown in Fig. 37 is commonly employed in office buildings. Another class of buildings where the same apparatus is used, although the amount of exhaust steam is very small, includes schoolhouses in which a combination of direct and steam-blast heating is used, the fan being driven by a steam engine. In cases of this kind a pressure of 30 to 40 pounds is carried on the boilers for operating the fan engine, while it is reduced to about 10 pounds for the main heater, and 2 to 3 pounds for the direct surface. The exhaust steam from the engine and pumps may be turned into the general heating system, after passing through an oil separator, or may be condensed in a separate section of the main heater, and the condensation containing the oil trapped to the sewer. Each system operated under a different pressure is provided with its own reducing valve and trap, and an automatic pump and receiver is used for returning the condensation to the boilers.

Similar systems are used in hospitals, where a pressure of 60 pounds or more is required for laundry work, with 20 to 30 pounds for sterilizing, 10 pounds for cooking, and 2 to 3 pounds for heating. The exhaust, in this instance, might be simply that from the return pump, but the general method of making the connections would be practically the same as in Fig. 61.

TEST QUESTIONS:

(1) In what ways does a system of exhaust steam heating differ from an ordinary low-pressure gravity system?

(2) Describe one form of oil separator.

(3) What is the use of an exhaust head?

(4) Why is a back-pressure valve necessary in exhaust heating?

(5) What is a pressure-reducing valve? Describe one form.

(6) What is the use of a steam trap? Describe the action of a float trap.

(7) What is a return trap? Describe its action by means of a diagram.

(8) What arrangement is used for returning the condensation to the boilers in a plant of large size?

(9) What is a pump governor? Show how it should be connected with a heating system.

(10) What two types of feed-water heaters are used with exhaust-heating systems?

(11) How is the sediment and scum removed from a closed heater?

(12) How is the capacity of a closed feed-water heater rated?

(13) What are the principal parts of a combination heater of the open type?

(14) Show by a diagram the method of making the pipe connections with the different pieces of apparatus in an exhaust-steam heating system.

(15) In what classes of buildings is exhaust-steam heating most frequently used?

CHAPTER VIII

Hot Water Heating

The term hot water heating applies to all cases where hot water is circulated through the coils and radiators in place of steam. It includes direct and indirect heating, and both the gravity and forced systems of circulation. The principle involved in the gravity circulation of hot water has already been explained in Chapter I, but its practical application to the warming of buildings is more clearly illustrated in Figs. 64 and 65. Let a glass tube be bent in the form shown in Fig. 64. Nearly fill this with water through the open end, and hold a small spirit lamp close to the leg "a" of the tube. By watching the bubbles which are formed it will be seen that a circulation has been set up in the direction shown by the arrows. This is due entirely to the difference in temperature and weight of the water in the legs "a" and "b" of the tube, as already described. Any increase in volume, due to the higher temperature, is taken up by the water rising to a higher level in the open end of the tube "a."

In Fig. 65 the lamp and tube are replaced by a boiler and system of piping. An expansion tank takes the place of the open end of tube "a," and a radiator is inserted in the horizontal line connecting the supply and return pipes.

The water becoming heated in the boiler rises in the supply pipe, and entering the radiator is cooled sufficiently to produce a difference in weight which causes it to pass down the return pipe, thus forcing the warmer water from the boiler up the supply pipe again. This action being continuous produces a constant circulation through the system as long as a fire is maintained in the furnace beneath the boiler. The increase in volume overflows into the expansion tank, and is returned again when the temperature falls.

The force producing a gravity circulation varies directly with the difference in temperature of the water in the supply and return pipes, and with the height of the radiator above the boiler. That is, the greater the difference in temperature of the ascending and descending columns of water, the greater the unbalanced weight in the return pipe. This naturally increases the velocity of flow. Again, the greater

the height of the unbalanced columns, the greater their difference in weight; this also increases the velocity of flow. On the other hand, long horizontal runs of piping, and changes in direction, add to the friction and so reduce the velocity. This fact limits the size of building to which the gravity system of hot water heating may be applied, and makes it necessary in cases of this kind to provide some means for mechanical circulation.

Systems of Piping. Although several systems of piping are used in hot-water heating, they are divided somewhat differently than in

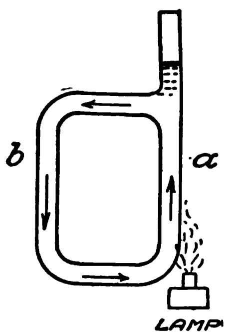


FIG. 64

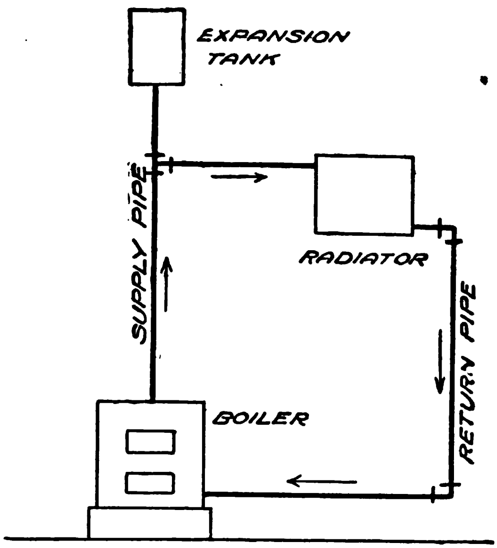


FIG. 65

the case of steam. This is because all radiators and coils must have two connections in order to produce a circulation through them. Special fittings are sometimes used which give the appearance of a single connection; but these have two internal passages, one for the supply and one for the return, which are connected with the supply and return risers outside of the radiator. The most common system of hot water piping is shown in diagram in Fig. 66. In this arrangement all horizontal mains are in the basement, and the supply and return risers are carried to the radiators on the upper floors as indi-

cated. One or more main-supply pipes are taken from the top of the boiler and are connected with the various risers by means of suitable branches, and the returns are made in a similar manner. An expansion pipe is carried from the main near the top of the boiler to the expansion tank, which should be placed above the highest radiator.

If connected with the main, the expansion pipe should be taken off *inside* the stop valves, as shown in Fig. 66, and should *not* in any case be provided with means for shutting off. This is the safety-valve of the system, and if furnished with a valve it might be closed

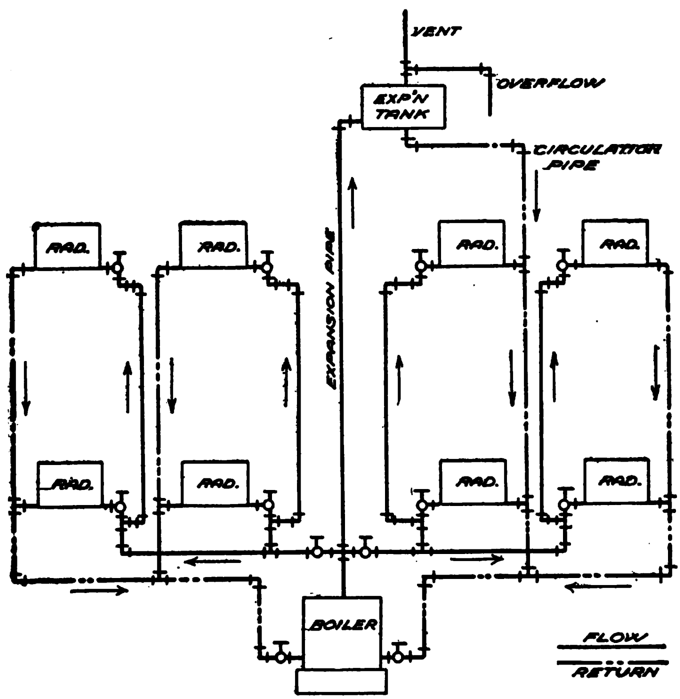


FIG. 66

through carelessness and result in a dangerous explosion when the water expanded under a higher temperature. Oftentimes the expansion pipe is connected with some high point in the system, to avoid the expense of running a separate pipe. This should never be done if there is a valve in the line between the boiler and the tank.

Sometimes this arrangement is resorted to and a safety valve placed on the boiler. This is much better than having no relief at all; but safety valves often become rusty and are liable to stick if not tested frequently.

The best arrangement in all cases is to run a separate pipe from the boiler to the tank, without valves, and this can usually be done without difficulty.

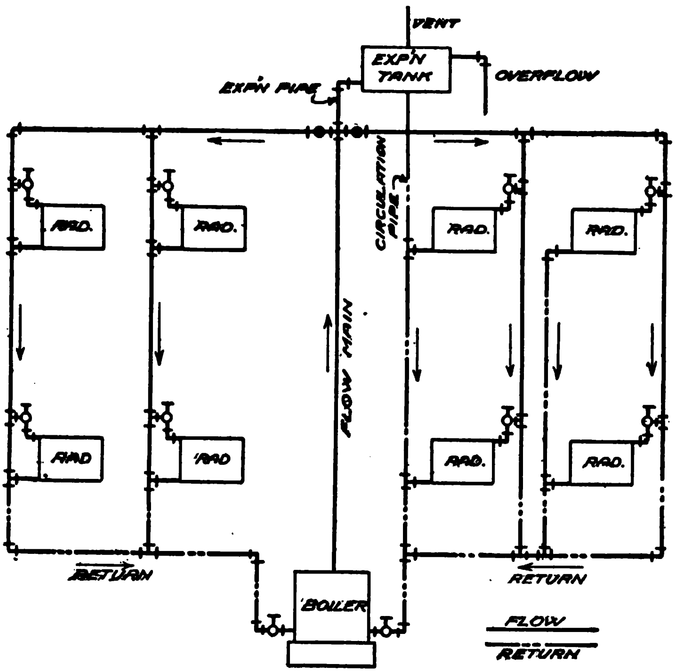


FIG. 67

Overhead Distribution. An especially desirable system of piping for buildings having an attic or roof space is shown in Fig. 67. In this case the flow main supplying the entire system is carried to the attic, where it branches and feeds the various supply drops at the top. The radiators at the left have two connections with the drops, one at the top and one at the bottom, at the same end, as shown. This makes it necessary to use only one drop or riser instead of two, as shown in Fig. 66, and is therefore somewhat cheaper to install.

Another desirable feature in connection with this system of piping

is that only half the number of risers appear in the lower-floor rooms, which is often a matter of considerable importance. When used in tall buildings it is necessary to increase the amount of radiation slightly on the succeeding floors downward, because the return from each radiator flows back into the supply drop, and therefore cools the water somewhat before it reaches the radiators on the floor below. In dwelling houses of two and three stories it makes very little difference, and if the supply drops are made of good size it is not necessary to change the radiating surface on this account.

The expansion pipe in this case is taken from the top of the main, inside the shut-off valves, which are placed in the branches as shown. The radiators at the right have the usual double connection; that is, with the supply and return at opposite ends. In this case the supply is at the top of the radiator instead of at the bottom, as in Fig. 66. This makes a continuous downward flow through the radiator and reduces the friction somewhat, which is a desirable feature. A bottom supply to a radiator will usually work well on the downward system, but the top connection shown at the right is preferable. It is customary to place a valve in the supply connection only, in hot water heating, as this is all that is necessary to regulate or shut off the circulation through a radiator.

In large buildings valves are placed at the top and bottom of each riser, for closing in case of repairs to any of the radiators on that line, without shutting down the rest of the system.

Combination Piping. Fig. 68 shows a method of running the piping for a combined direct and indirect-heating system, the supply or flow mains being separate, while the return mains are common to both. The overhead system of distribution is used for the direct radiators the same as in Fig. 67, both connections being at the same end of the radiator. The indirect stacks are supplied through separate branches taken off from the main riser in the basement.

The returns from all radiators, both direct and indirect, are connected into the same mains and carried to the boiler, as shown.

Choosing a System of Piping. Here, as in steam heating, no rules can be given for determining the best system of piping in any particular case. Much will depend upon the personal ideas of both the owner and the engineer in regard to the appearance of the pipes and radiator connections exposed in the rooms. In a general way, it is likely that the arrangement shown in Fig. 66 is used more fre-

quently than any other for the ordinary two-story dwelling house. This is adapted to both direct and indirect heating, or to a combination of the two.

The overhead system (Fig. 67) is used extensively in tall buildings and in dwellings of large size, where there is ample room for running the supply mains in the attic. Some engineers use this arrange-

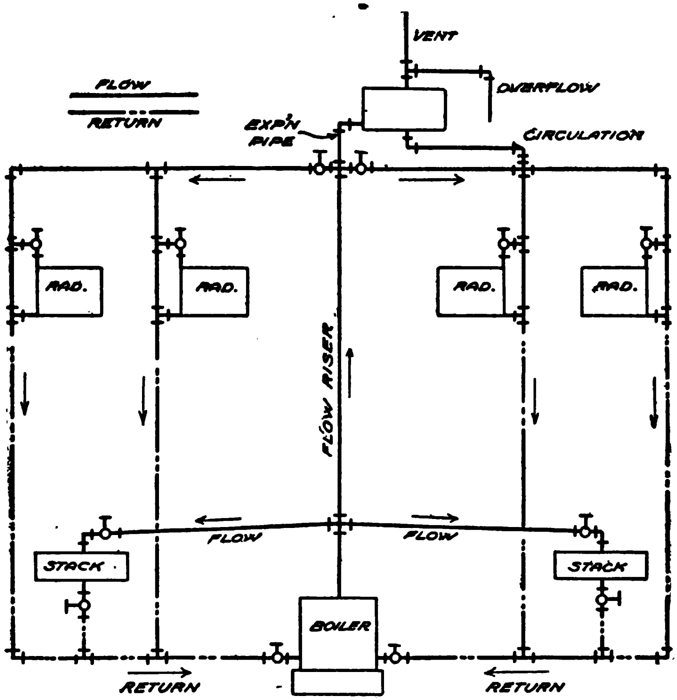


Fig. 68

ment altogether, as it has the advantage of establishing a circulation quickly and evenly when first starting up. With the basement distribution and upward feed, there is some danger of short circuiting and uneven circulation through different parts of the system, unless particular care is taken in laying out the mains and branches. This is especially true in large buildings where there are long runs of horizontal piping.

Radiator Connections. In making the radiator connections for a system of steam heating the principal point to be kept in mind is the matter of drainage.

With hot water, short circuiting is the condition to be guarded against.

First-floor radiators should be favored on account of their small elevation above the boiler. A common method of making the connections in this case is shown in Fig. 69, the direction of flow being indicated by the arrows. As the hottest water flows along the upper part of the main it is evident that a supply riser having a top connection, as in Fig. 69, will have an advantage over one connected with the side of the main. On the other hand, the cooler water from a radiator will pass into the return more freely if the connection is made on the side, owing to the lower temperature near the bottom of the pipe. Fig. 70 illustrates the usual way of connecting the risers to upper-floor radiators with the basement mains. In this case there is a tendency to a more rapid circulation, owing to the greater elevation of the radiator above the boiler. This is offset by connecting the supply riser in the side of the main instead of in the top, as in the previous case. In Fig. 71 risers to both the first and second floors are taken from the same branch instead of being connected with the mains independently.

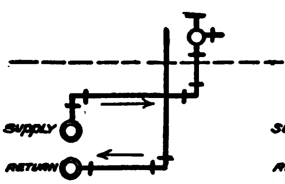


FIG. 69

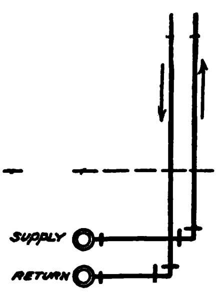


FIG. 70

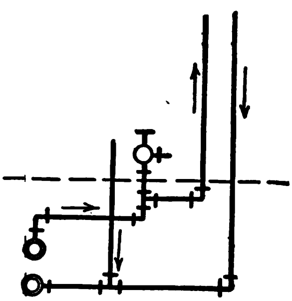


FIG. 71

Under these conditions the flow is equalized by connecting the first-floor radiator with the top of the riser, and taking the supply for the upper floor from the side, as shown. The return from the first floor, in this case, is connected into the top of the return branch. While this will work satisfactorily in the arrangement shown, it is well to use the side connection for all returns when possible.

In tall buildings the same care must be taken regarding expansion as described for steam. While the average temperatures in hot-water

heating are lower than with steam, it frequently happens that it rises nearly to the boiling point for short periods in the coldest weather, so that practically all that has been said in connection with expansion strains in low-pressure steam heating applies equally well to hot water.

Although long-turn fittings should be used in the mains, the short or regular pattern are best adapted to the radiator connections, and are also used to a considerable extent in connecting the risers with the mains.

The ordinary form of angle or gate valve is generally employed for hot-water work, as well as for steam, although special quick-opening valves are used to some extent. Union valves have already been mentioned in connection with steam heating. As valves are not commonly used on the return end of water radiators, a union elbow is often substituted for the regular fitting, which makes the radiator easily removable in case of repairs.

Air Venting. A complete removal of the air from the pipes and radiators of a hot-water system, as fast as it collects, is necessary to its successful operation. Air, being lighter than water, rises to the high points in the radiators and piping as it is liberated from the water in the boiler; hence, air vents must be placed at these points for its removal. Although automatic air valves, adapted to hot water heating, are employed to some extent, the damage which would result to floors and ceilings, if one should stick while open, makes their use somewhat risky in fine dwelling houses and similar buildings. The ideal arrangement is one in which the removal of air is made practically automatic without the use of valves or other mechanical devices. As the expansion tank is always open to the atmosphere, in the usual form of heating, the air can be expelled through this by a suitable arrangement and grading of the pipes.

As the greater part of the air is liberated in the boiler, and rises with the water through the flow main, it is evident that a pipe connected into the top of the main riser, directly above the boiler, and carried to the expansion tank, will remove a large proportion of the air and prevent it from reaching the radiators. In Fig. 66 the expansion pipe performs the office of air vent in the manner above described. The only pockets in the system for the accumulation of air, with properly graded mains, are in the tops of the radiators, and these should be provided with hand pet-cocks for occasional use, as

may be needed. All supply mains to radiators on the upper floors should grade upward from the boiler to the foot of the risers, and the return mains should grade downward toward the boiler. The arrangement of the piping in Fig. 67 is ideal for the removal of air without the use of air valves. In this case the greater part of the air liberated passes off directly through the expansion pipe which is connected into the top of the flow main or riser. An inspection of the radiators and their connections will show that the system contains no pockets whatever for the accumulation of air. The highest points in the radiators are vented through the top or supply connections, and the supply branches in the attic grade upward toward the expansion pipe, so there is a continuous upward passage from all parts of the system to the expansion tank. Fig. 68 is the same as that just described, except for the indirect stacks in the basement. These may be vented in a similar manner to the direct radiators by grading the supply branches downward from the main riser to the stacks, and making the connections in the top, as shown. In cases where indirect stacks are used with the system of piping, shown in Fig. 66, air valves should be connected into the top of each stack. Either the hand pet-cock or the automatic valve may be used in this case, as the damage from leaks will be much less in the basement than if they occurred on the upper floors.

Air valves on indirect stacks should always be brought out through the casing and made easily accessible for adjustment or manipulation.

Expansion Tank. The expansion tank is usually cylindrical in form, made of heavy sheet steel and galvanized. When there is plenty of head room they are commonly placed in a vertical position, and the connections made as shown in Fig. 72. This is adapted to locations where there is danger of freezing and the pipe connections are such as to keep the water in the tank warm as long as there is a fire in the furnace.

The expansion pipe is connected into the tank a short distance above the bottom and a circulation pipe, so called, is taken from the bottom and connected into a nearby return, as shown in Figs. 67 and 68. This arrangement produces a constant circulation of water through the tank, keeps it warm, and thus prevents freezing. When the circulation pipe is used the tank should be covered with some good form of insulation to prevent the waste of heat by radiation. When the tank can be placed in a warm room the circulation pipe

may be omitted. The vent pipe should be carried up some distance above the tank, and preferably through the roof of the building. Should the temperature of the water be raised too high, boiling will first take place in the tank, that being under the least pressure, and in case of such an event water is liable to be thrown out of the vent pipe; hence, it is best to carry the pipe through the roof as a precaution.

The overflow is best carried to the basement and made to discharge over an open sink; it then acts as a "tell-tale" for showing when the tank is full. With this arrangement the system may be filled through a connection in or near the boiler.

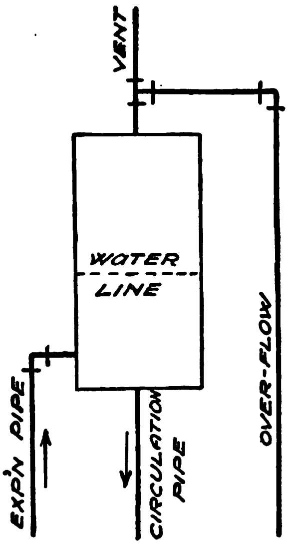


Fig. 72

It is always best to fill up the piping and radiators from the bottom, as this forces out the air and prevents it from becoming pocketed, as it is liable to do when filled from the top. In some cases water connections are made both with the boiler and with the expansion tank, the former for first filling up the system and the latter for adding water from time to time after it is in operation. Fig. 73 shows an arrangement for maintaining a constant water level automatically by means of a ball cock.

When this is used, a handhole should be provided over the float, as shown, or an open tank may be used.

Altitude gauges are commonly connected with the piping in the basement for indicating the height of the water level in the system.

The colored or index hand is set to indicate the normal level, and any variation from this will be shown by the movable pointer. This arrangement is very convenient when filling the system from the bottom.

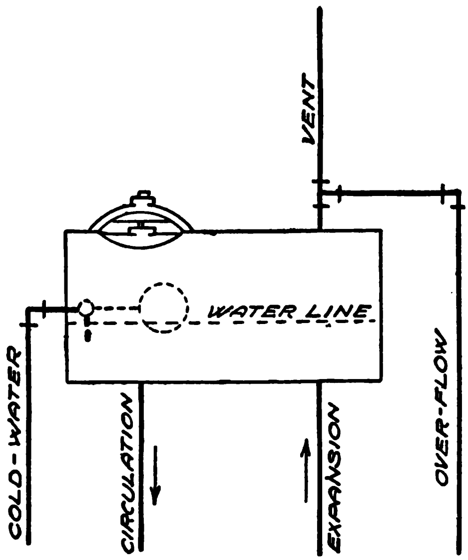


FIG. 73

TABLE XI

Size of tank	Gallons capacity	Square feet of radiation
10″ × 20″	8	320
12″ × 20″	10	400
12″ × 30″	15	600
14″ × 30″	20	800
16″ × 30″	26	1,040
16″ × 36″	32	1,280
16″ × 48″	42	1,680
18″ × 60″	66	2,640
20″ × 60″	82	3,280
22″ × 60″	100	4,000

The common method of computing the size of expansion tank is to divide the square feet of radiation (both direct and indirect) by 40, which gives the required capacity in gallons.

Table XI gives dimensions and capacities of standard sizes of expansion tanks, together with the square feet of radiation with which they may be used, based on the above relation.

Location of Radiators and Risers. The radiators are placed in practically the same manner as for steam heating, although the larger size required makes it more difficult, in some cases, to find a suitable location.

In laying out the risers, and in fact, all parts of the piping, care must be taken not to run pipes in exposed locations where there would be danger of freezing should the circulation stop, either through radiators being shut off, or short circuiting in other parts of the system. If, for local reasons, it becomes necessary to carry up a riser in an outside wall, or other exposed position, it should be thoroughly insulated with some good form of sectional covering.

With direct radiation, the returns are usually carried back to the boiler at an elevation, near the basement ceiling, as they are more out of the way in this location. When indirect stacks are employed, the returns are run along the building walls near the floor and in trenches, the same as sealed returns in steam heating.

Boiler Connections. The connections for a pair of boilers are similar to those for steam heating, as shown in Fig. 41, except for the check valve in the return and the equalizing pipe.

Long-turn fittings should always be used about the boilers if possible, both in the supply and return. A separate expansion pipe is best taken from each boiler, although the branches are sometimes connected into one before carrying up to the tank.. This makes it necessary to place valves in the branches, for use when one of the boilers is shut down, and for this reason is not to be recommended. The best arrangement is to carry individual pipes from each boiler to separate expansion tanks, and omit all valves.

Indirect Heating. The arrangement of the heating stacks and casings is much the same as for steam heating. In selecting an indirect radiator, care should be taken to secure one especially adapted to hot water heating, for the reasons mentioned in Chapter IV. The areas of the flues and air ducts may be proportioned to the heating surface in a similar manner to that already described for steam, ex-

cept for the ratios used. In this case the cold-air ducts and the warm-air flues to the first-floor rooms may be given 1½ square inches area per square foot of heating surface in the stack, and 1 square inch area for the warm-air flues to the upper floors.

All that has been said regarding flue casings, dampers, and registers, in Chapter VI, applies to the present case equally well.

Indirect Stacks for Schoolhouses. It has been stated in a previous chapter that about 300 square feet of indirect steam radiation should be provided for each standard class-room. If hot water is used, this surface should be increased about 50 per cent., making 450 square feet per class-room. In this case the sizes of the supply and vent flues may be kept practically the same as for steam, because the air volume supplied is large, and the temperature of the entering air is comparatively moderate, even with steam. Hence, the conditions are not greatly changed by the substitution of hot water, except for using larger heating stacks.

Pipe Connections for Indirect Stacks. The best results are obtained if not more than 80 or 90 square feet of heating surface are connected to a single pipe.

In the case of larger stacks it is well to divide the surface into two or more groups, and run a separate branch to each. A single valve, however, is sufficient for each stack, this being placed in the main supply pipe before it branches to the different groups. In the case of steam, valves are usually placed in the branch pipe to each group of sections to assist in the temperature regulation; but with hot water this is done by varying the temperature of the water circulated through the system. Here, as in the case of direct heating, valves are commonly placed only in the supply pipe.

Pipe Sizes. As mentioned at the beginning of the present chapter, the velocity of flow increases with an increase in temperature between the supply and return, with the height of the radiator above the boiler, and diminishes with the length of the horizontal run. These conditions are all taken into account when computing the size of the piping for supplying any given amount of radiation. As it would be a long process to compute the sizes of all the pipes in a heating system, tables have been prepared based on the average conditions of hot water heating, which are generally used in practice.

Such tables are given below; the first for the basement mains in direct heating; the second for the supply risers and return drops, and the third for indirect stacks.

TABLE XII FOR BASEMENT MAINS

Size of basement main	Square feet of direct radiation. Length of main not over 100 feet	Square feet of direct radiation. Length of main 100 to 200 feet
1″	30	
1¼″	60	40
1½″	100	60
2″	200	100
2½″	300	200
3″	500	400
3½″	800	600
4″	1,100	800
5″	1,500	1,300
6″		1,800

TABLE XIII FOR RISERS

Size of riser	Square feet of direct radiation, 1st floor	Square feet of direct radiation, 2nd floor	Square feet of direct radiation, 3rd floor
1″	30	50	70
1¼″	60	90	120
1½″	100	150	190
2″	200	300	400
2½″	300	500	
3″	500		

TABLE XIV FOR INDIRECT STACKS

Size of pipe	Square feet of indirect radiation. Length of pipe not over 100 feet	Square feet of indirect radiation. Length of pipe 100 to 200 feet
1″	15	
1¼″	30	20
1½″	50	30
2″	100	50
2½″	150	100
3″	250	200
3½″	400	300
4″	750	650
5″		650

The corresponding supply and return pipes are always made the same size in hot water heating, because the same volume of water flows through both of them. Table XIV is computed on the basis that a given pipe will supply one-half the amount of indirect surface that it will in the form of direct. The square feet of surface given in Table XIV is for pipe lengths of 100 and 200 feet. For shorter lengths of 50 feet or less, the amount of surface supplied may be made 30 per cent. greater than given in column 2, if so desired. In practice it is usual to use the figures as they stand in the table, but the above shows how these may be overrun in special cases, if for any reason it is desirable not to change the size of pipe.

EXAMPLES:

(1) A basement main, 150 feet long, supplies 350 square feet of direct radiation. What size should be used?

SOLUTION.—From Table XII it is found that a 3-inch pipe 200 feet long will supply 400 square feet of surface, and is therefore ample.

(2) A riser supplies 100 feet of radiation on the third floor, and 150 feet on the first. What size should it be?

SOLUTION.—From Table XIII it is found that a 1¼-inch pipe will supply 120 feet of surface on the third floor, and therefore can be used from the first to the third floor.

If the radiators were both of the same size the conditions would be practically the same as though the total radiation, 250 square feet, was on the *second* floor. But the greater part is on the first floor, so the force producing the circulation will not be quite so strong as though it were equally divided between the first and third floors, or all on the second floor. Therefore a pipe must be used which is large enough to supply slightly more than 250 feet on the second floor. Table XIII shows that a 2-inch pipe will supply 300 feet of surface on the second floor, and is the size which would be used.

(3) An indirect radiator is situated 90 feet from the boiler, and contains 150 feet of radiating surface. What size of supply pipe should be used?

SOLUTION.—Table XIV shows that a 2½-inch pipe will supply 150 feet of radiation at a distance of 100 feet, and is the size to be used.

(4) An indirect radiator containing 360 square feet of surface is located 20 feet from the boiler. What should be the size of the supply pipe?

Solution.—Being considerably less than 50 feet run, a pipe size taken from column 2, Table XIV, will be large enough to supply a radiator 30 per cent. greater; or what is the same thing, select a

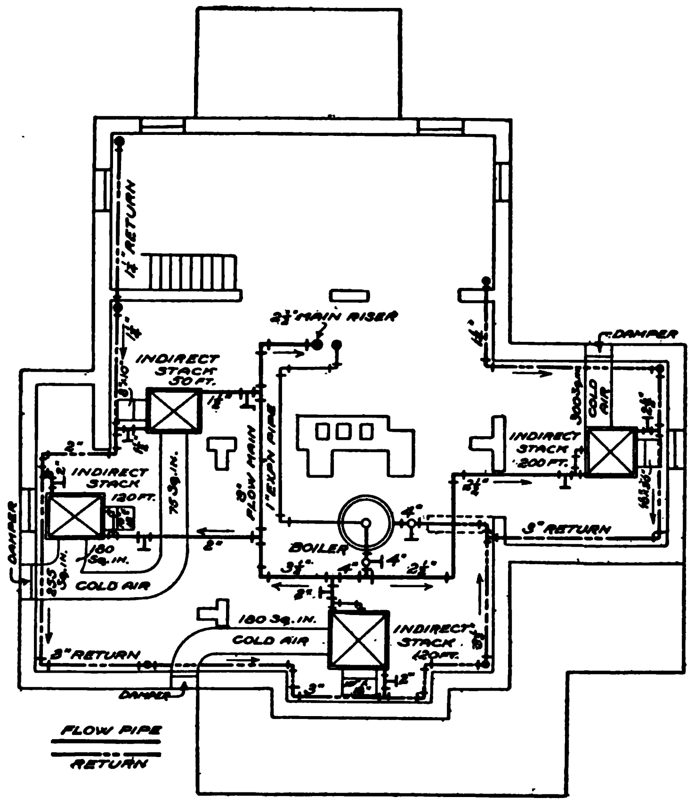


Fig. 74

size corresponding to a radiating surface of $360 \times 0.7 = 252$ square feet. Columns 1 and 2 of Table XIV show that a 3-inch pipe will supply 250 square feet, and is the size to be used.

As the heating surface supplied by a main is usually made up of a number of stacks located at varying distances from the boiler, it is necessary to assume some average point and make the main the same

size as though all of the radiation was located at this point, in a single stack. This will soon be learned by practice.

Plans. The plans for a hot water heating system are laid out in a similar manner to those for steam. The exposed flow pipes are drawn in full lines, and the returns with a dash and two dots.

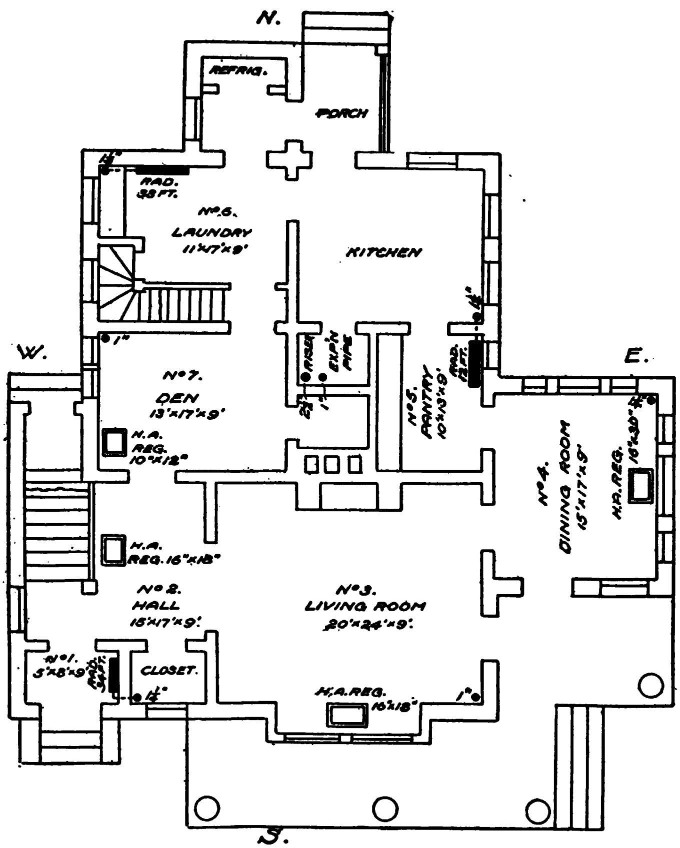


FIG. 75

Concealed pipes, like those in the attic space, Fig. 76, are usually dotted to distinguish them from exposed piping.

It is also a good idea to indicate, by means of arrows, the direction of flow in the principal lines of piping, as it is often of assistance to the fitter in reading the plans.

A Problem in Design. In order to fix the methods employed in hot water heating more clearly in mind, a practical example will now be given the same as for steam heating in Chapter VI.

Let the heating plans be drawn for a twelve-room house, as illustrated in Figs. 74, 75, and 76. The building is to be heated with hot water, direct radiators being used in all cases, except in the den,

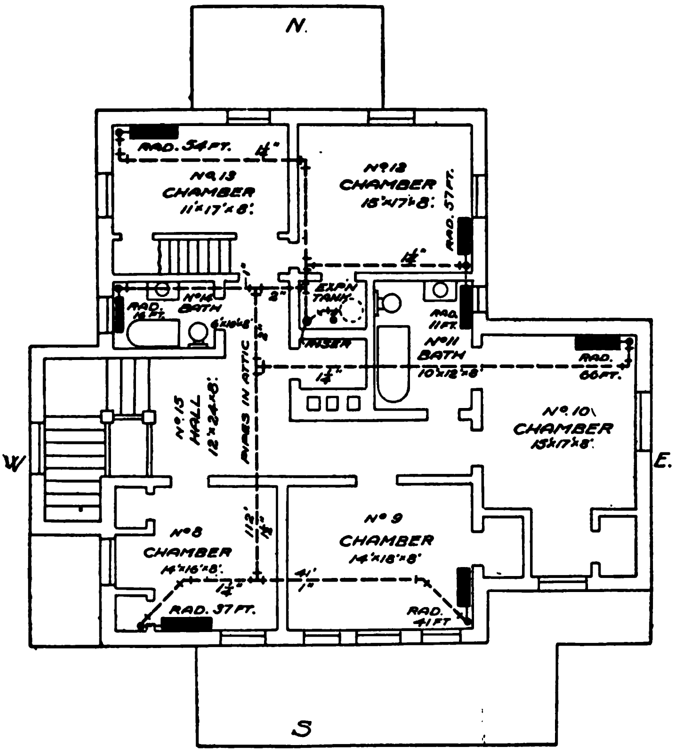


FIG. 76

hall, living room, and dining-room on the first floor, where indirect stacks are to be employed. Both the lower and upper halls are to be warmed by means of a single hot-air register placed in the floor of the lower hall.

The points of the compass are marked on the first and second-floor plans.

The building is to be of first-class construction, so that no extra allowance need be made for the effect of a cold attic when figuring the radiation for the second-floor rooms.

Measuring up the exposed wall and window surface, counting outside doors as glass, the following results are obtained:

First Floor	*Net Wall*	*Glass*
Room No. 1	72 sq. ft.	32 sq. ft.
" " 2	111 " "	24 " "
" " 3	216 " "	92 " "
" " 4	247 " "	176 " "
" " 5	18 " "	18 " "
" " 6	111 " "	24 " "
" " 7	81 " "	36 " "
Second Floor		
Room No. 8	104 " "	40 " "
" " 9	126 " "	50 " "
" " 10	250 " "	55 " "
" " 11	17 " "	15 " "
" " 12	216 " "	40 " "
" " 13	184 " "	40 " "
" " 14	30 " "	18 " "
" " 15	215 " "	25 " "

The direct radiation for a southern exposure is next obtained for all of the rooms by dividing the wall surface by 8, the glass surface by 2, and adding the results. The surface in room No. 1 is increased 20 per cent. for leakage around the front door.

First Floor	*Direct Radiation*
Room No. 1	25 sq. ft.
" " 2	26 " "
" " 3	73 " "
" " 4	119 " "
" " 5	11 " "
" " 6	26 " "
" " 7	28 " "

Second Floor	*Direct Radiation*
Room No. 8	33 sq. ft.
" " 9	41 " "
" " 10	58 " "
" " 11	10 " "
" " 12	47 " "
" " 13	43 " "
" " 14	13 " "
" " 15	40 " "

Corrections are now made for exposure, and those radiators which are to be of the direct form are multiplied by 1.5.

First floor	Exposure	Factor	Direct Surface	Indirect Surface
Room No. 1	S.W.	1.10	34	
" " 2	W.	1.20		47
" " 3	S.E.	1.05		116
" " 4	N.E.S.	1.13		202
" " 5	E.	1.10	12	
" " 6	N.W.	1.25	33	
" " 7	W.	1.20		51
Second Floor				
Room No. 8	S.W.	1.10	37	
" " 9	S.	1.10	41	
" " 10	N.E.S.	1.13	66	
" " 11	E.	1.10	11	
" " 12	N.E.	1.20	57	
" " 13	N.W.	1.25	54	
" " 14	W.	1.20	16	
" " 15	W.	1.20		72

The final radiating surfaces are found by making the corrections for exposure, in the case of the direct radiation, and by correcting for exposure and multiplying by 1.5 for the indirect surface.

The radiators and piping are now drawn in, the overhead system with a downward distribution being used for the direct surface. Both the supply and return connections are at the same end of the radiator and connect with the same riser, as shown in Fig. 68. The indirect stacks are on a separate line, as illustrated in the same cut.

The returns from both the direct and indirect surface enter the same mains, which are carried along the outer walls of the building, as shown in Fig. 74. The main riser for supplying the direct radiation, and the expansion pipe, are both carried to the attic through closets, where the former branches and connects with the various supply drops, while the latter enters the expansion tank. The surface in the indirect stacks is made a multiple of 10, on account of the radiator sections being made that size, for the pattern used. The pipe sizes for the attic-supply mains and drops, and for the main riser, are taken from Table XIII, column 3, for second-floor radiation.

The basement mains are taken from Table XIV, column 2, and are reduced one size in some cases on account of the short run.

The cold-air ducts and the warm-air flues are figured on a basis of $1\frac{1}{2}$ square inches of area per square foot of heating surface in the stack. The registers are made approximately 50 per cent. larger than the warm-air flues connecting with them.

The next step is to compute the grate area in the boiler.

The equivalent square feet of direct radiation in the building is 1,341, and this multiplied by 170 calls for 227,970 *TU* per hour to be supplied by the boiler. Looking in Table III it is found that a "Class B" boiler will supply 32,000 *TU* per hour per square foot of grate.

Therefore, $227{,}970 \div 32{,}000 = 7.12$ square feet of grate area are required, which is practically a 36-inch round grate.

Assuming a chimney 40 feet in height; it is found from Table V that an 11-inch flue will be required.

Forced Circulation. Forced circulation is used in large buildings where the radiators are located at long distances from the boiler. As the velocity of flow is greatly reduced by the friction in long pipes, it would require mains of excessive size if natural or gravity circulation were depended upon in cases of this kind.

Pumps. Centrifugal pumps are commonly used for this class of work, driven either by a steam engine or electric motor. Steam turbines are well adapted to this purpose, as the exhaust can be turned into the heater and utilized, so that the matter of steam economy is not one of importance. A centrifugal pump and direct-connected turbine are shown in Fig. 77, the latter being at the right in the cut. When reciprocating engines or electric motors are used, it is cus-

tomary to employ the direct-connected arrangement shown in Fig. 77, being more compact.

Centrifugal pumps are rated in the gallons per minute which they will force against a given pressure head, usually expressed in feet. For example, if a pump has a capacity of 400 gallons per minute, with a 30-foot head, it means that this quantity of water will be raised per minute to a height of 30 feet, or will be forced against a pressure per square inch equal to the weight of a column of water 1 inch square and 30 feet high.

Heaters. Forced hot water heating is commonly used in connection with power plants in mills and office buildings, and the water heated by exhaust steam, or a combination of exhaust and live steam,

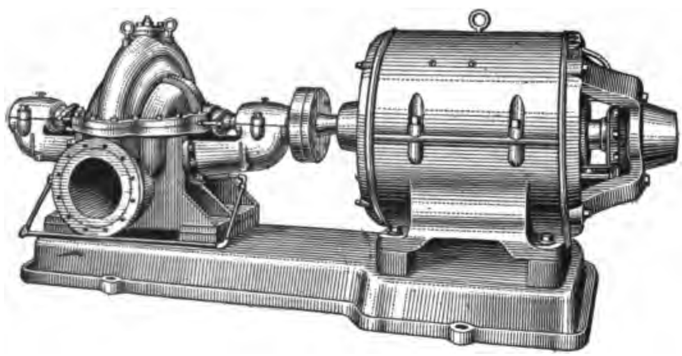


FIG. 77

in heaters similar to those used for feed-water heating (see Fig. 61), the only change being a reversal of the steam and water connections; that is, the steam is *inside* the tubes and the water passes over them, while flowing through the shell of the heater. Under average conditions, with the water flowing to the radiators at a temperature of 190°, and returning at 160°, and with the heater supplied with steam at atmospheric pressure; there should be about 1 square foot of tube surface in the heater for each 42 square feet of direct radiation supplied. Commercial feed-water heaters are built on a basis of ⅓ of a square foot of heating surface per horse power; hence, the heater must have a rated capacity of one horse power for each $42 \div 3 = 14$ square feet of direct heating surface.

EXAMPLES:

(5) A building contains 5,000 square feet of direct radiation. It is to be warmed by forced circulation, and steam at atmospheric pressure is to be supplied to the heater. How many square feet of tube surface should the heater contain?

SOLUTION.—$5{,}000 \div 42 = 119$ square feet.

(6) What should be the rated horse power of a heater to supply 4,000 square feet of direct radiation and 3,000 square feet of indirect, under the usual conditions of forced hot-water circulation?

SOLUTION.—Counting 1 square foot of indirect surface as 2 of direct, there is a total of $4{,}000 + (2 \times 3{,}000) = 10{,}000$ feet. Hence, a heater having a rated capacity of $10{,}000 \div 14 = 714$ horse power is called for.

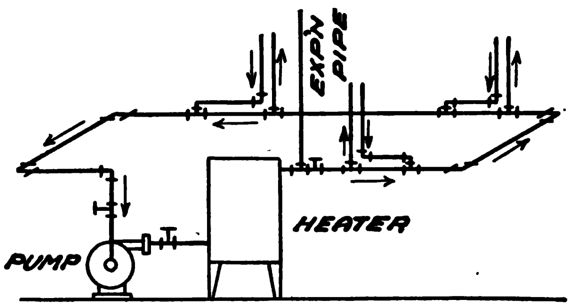


FIG. 78

Systems of Piping. There are two arrangements of piping in common use with this system of heating; the circuit system, shown in Fig. 78, and the two-pipe system, in Fig. 79. In the former a circuit main is carried around the outer walls of the basement and back to the heater through the pump, as shown. Supply risers to the floors above are taken from the top of the main, and the return drops are connected into the side of the same main at a point 6 or 8 feet beyond. The difference in pressure in the main, between these two points, is sufficient to produce a circulation through the supply and return risers and the radiators connecting them.

In the two-pipe system (Fig. 79) a supply main extends from the heater to the farthest supply riser, while a return main starts with the nearest return drop and extends back to the circulating pump.

All supply risers are taken from the supply main and all return

drops are connected into the return main. With this arrangement, throttle valves must be placed in the risers to regulate the flow and equalize the distribution throughout the system.

Pipe Sizes. The sizes of the supply and return risers for the circuit system may be made the same as for gravity circulation, and those for the two-pipe system one size smaller.

Under ordinary conditions about 1.2 gallons of water per minute should pass through the main for each 100 square feet of direct radiation to be supplied.

Table XV gives the capacities of pipes of different sizes for the velocities commonly employed. These vary from 300 to 600 feet per minute, according to the size of the pipe.

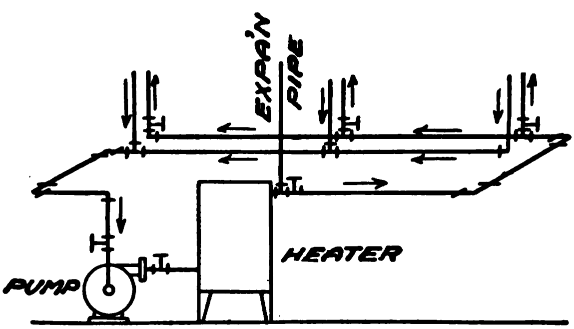


FIG. 79

TABLE XV

Diameter of main in inches	Capacity in gallons per minute
3	100
4	250
5	400
6	700
7	1,000
8	1,500

EXAMPLES:

(7) A building contains 18,000 square feet of direct radiation. What should be the size of the circuit main for forced hot water circulation?

SOLUTION.—$180 \times 1.2 = 216$ gallons of water to be circulated per minute. Looking in Table XV it is found that this quantity comes between the capacity of a 3-inch and a 4-inch pipe, and the larger size would be used.

(8) The two-pipe system of forced hot water circulation is to be used in a building containing 20,000 square feet of direct radiation. What should be the size of the supply and return mains in their largest parts, near the pump and heater?

SOLUTION.—$200 \times 1.2 = 240$ gallons per minute, which from Table XV calls for 4-inch pipes.

Having determined the size of the supply main where it leaves the heater, intermediate points can be proportioned according to the amount of radiation taken off. The size of the return main should be the same as the supply, except reversed in direction. The circuit main is made the same size for its full length.

TEST QUESTIONS:

(1) What systems are included in the term hot water heating?

(2) What is the effect upon the circulation of increasing the temperature difference between the supply and return pipes?

(3) What effect does the elevation of the radiator above the boiler have upon the force and rapidity of circulation through it?

(4) How many pipe connections must a hot water have to operate satisfactorily?

(5) Show by means of simple diagrams two common systems of hot water piping.

(6) How do the connections with first-floor radiators differ from those on the upper floors?

(7) What is the best method of air venting a hot water heating system?

(8) How are the pipes graded for supplying an indirect stack?

(9) What is the use of a circulation pipe on an expansion tank?

(10) How is the capacity of an expansion tank computed?

(11) What precaution should be observed in the location of pipes and risers?

(12) When two boilers are used, what arrangement of expansion pipes and tanks should be used?

(13) How are the flue areas determined in hot water indirect heating for dwelling houses?

(14) What is the largest amount of indirect heating surface which should be supplied from a single branch pipe?

(15) Are the pipe sizes usually computed in each particular case in hot water heating?

(16) What form of pump is used in forced hot water circulation? How is it usually driven?

(17) What is meant by the term "pressure head" in connection with the action of a pump?

(18) How is the water usually heated in a system of forced circulation?

(19) What should be the relation between the tube surface in the heater and square feet of radiation to be supplied?

(20) What two systems of piping are commonly used in forced hot water heating?

(21) How is the size of main supply pipe computed?

CHAPTER IX

Special Systems of Heating

In addition to the regular methods of heating described in the previous chapters, there are a number of special systems, most of them patented, which are used more or less frequently.

The main objects of these are the rapid and complete removal of air from the pipes and radiators, and the regulation of the amount of heat given off.

Vacuum Systems. One of the simplest vacuum systems is that made by substituting vacuum air valves, so called, in place of the usual automatic valves or hand pet-cocks. These valves are so constructed as to allow the air to pass out of the radiators when the steam back of it is slightly above that of the atmosphere. When the steam pressure falls below the atmosphere, the valve remains closed and does not allow the air to enter the radiator. When the two-pipe system is used, air valves are often omitted from the individual radiators and a single vacuum valve is connected into the main return pipe just as it drops to enter the boiler. This arrangement can only be applied to a system having an overhead or dry return, otherwise the air would become pocketed in the return drop from each radiator, or each series of radiators. When the returns are sealed, vacuum air valves should be placed on each radiator.

The advantage of this system comes from the ability to run it on pressures somewhat below that of the atmosphere, thus reducing the temperature of the radiators in mild weather. In other words, the particular object sought is temperature regulation within a limited range. Before operating as a vacuum system, the steam pressure must be raised sufficiently to force out the air, and must also be repeated at more or less frequent intervals to remove that which may find its way in through small leaks in the pipe joints and valves.

The principle involved in another system of vacuum heating adapted especially to dwelling houses and similar work is shown in Fig. 80. In this arrangement the return valve on the radiator is replaced by a small expansion trap, which opens to allow the passage of air and condensation, but closes in the presence of steam. The

return pipe, instead of connecting directly with the boiler, empties into a tank placed some distance above it, as shown. The bottom of the tank is connected with the boiler below the water line by pipe "a."

A pipe "b" is taken from the top of the tank and carried, as shown, to a point a short distance below the normal water line in the boiler, which seals its lower end. When in operation a partial vacuum exists in the tank, being shut off from the boiler by the water seals in pipes "a" and "b." The difference in pressure in the boiler and tank being balanced by the water columns in the two

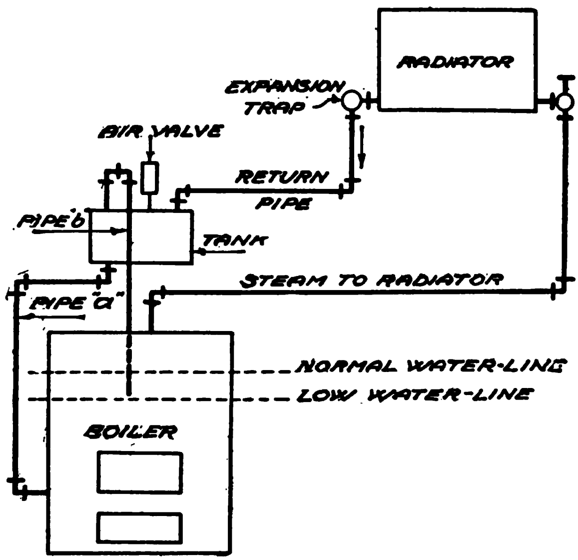


FIG. 80

pipes. As the condensation collects in the radiator it is discharged into the return pipe by the expansion trap and flows into the tank. As the water accumulates in the tank, not being able to return to the boiler on account of the higher pressure, the water line is lowered until the lower end of pipe "b" is uncovered, thus admitting boiler pressure to the top of the tank and allowing the water which it contains to flow into the boiler by gravity. This again seals the end of the equalizing pipe "b," and the steam contained in the tank soon condenses, thus producing a partial vacuum as before, and the opera-

tion is repeated. Any air contained in the radiators passes with the condensation into the tank and is expelled from the same while the tank is under pressure through an automatic vacuum air valve.

The purpose of this system is a quick removal of the air and condensation from the radiators, without the loss of steam; this being due to the suction in the return pipe caused by the vacuum in the tank.

In the arrangement shown in Fig. 81 the air valve is replaced by a "retarder," shown in section in Fig. 82. This has a minute opening,

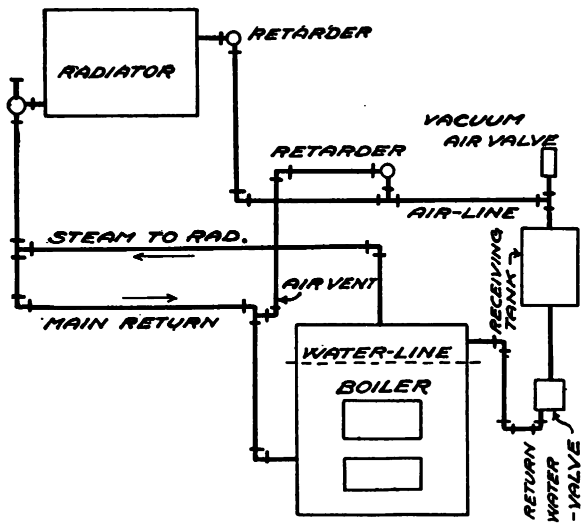


FIG. 81

and when under pressure allows air and steam from the radiator to pass continuously into the air-line piping, which in turn connects with a receiving tank near the boiler. A connection through a retarder is also made between the main return and the receiving tank, as shown. In the top of the tank is a vacuum air valve for exhausting the air when under pressure.

In operating this system a steam pressure of 1 pound or more is raised in the boiler, and the air expelled from the radiators through the retarders into the receiving tank. From here it passes into the atmosphere through the vacuum air valve. The fire is now checked

and the pressure dropped to a point where the temperature of the steam is just sufficient to give off the required amount of heat for warming the building. Any steam which passes through the retarders is condensed in the receiving tank, where it collects until the pressure

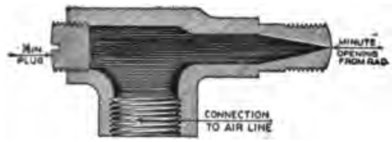


FIG. 82

drops to zero, upon which it passes into the boiler through the "return-water valve," which is located just below the tank.

The advantages claimed for this system are practically the same as for the preceding; that is, a quick removal of air from the radiators and a certain range of temperature regulation in the rooms.

In the arrangement shown in Fig. 83 the radiator has the usual steam and return connections, the condensation flowing back to the

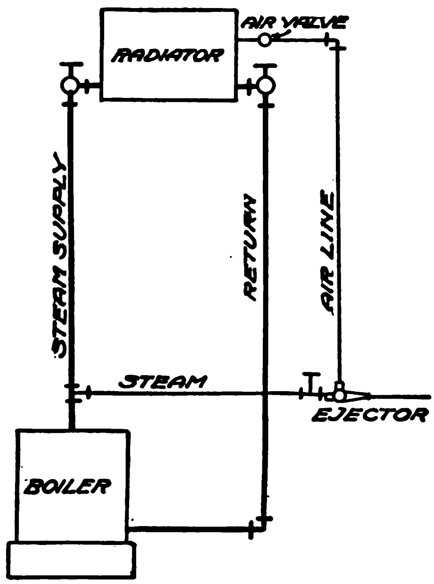


FIG. 83

boiler by gravity. An automatic air valve of the expansion type is placed on the radiator and connected with a line of air piping in which a vacuum is maintained by means of an ejector operated by

steam pressure from the boiler. The object of this device is the quick removal of air from the radiators, which results in a rapid circulation of steam under normal conditions. This system is equally well adapted to exhaust heating where the water flows to a return tank and is pumped back to the boilers, and is largely used in this class of work.

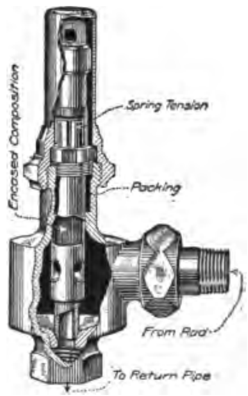


FIG. 84

A system commonly employed with exhaust heating, in connection with power-plant work, consists in placing thermostatic valves or traps upon the return ends of the radiators and connecting a vacuum pump to the end of the main return. The office of the thermostat is to allow only air and condensation to pass from the radiator into the return pipe, while the vacuum pump creates a suction which draws out all air and water as it collects, and also permits the use

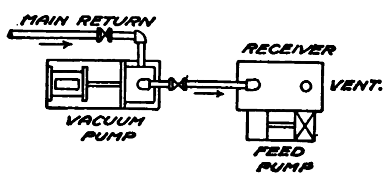


FIG. 85

of steam at less than atmospheric pressure in the radiators. This last condition is of much importance in exhaust heating, as it reduces the back pressure on the engines and so prevents the loss of power, which follows when the exhaust is turned into a pressure system.

From the vacuum pump the mixture of air and water is discharged into a vented receiver which allows the air to separate and pass out, while the water is returned to the boilers by means of a feed-pump. Fig. 84 shows one form of thermostatic valve for use with systems of this kind. When in operation the valve remains slightly open and allows the air and water to be sucked through into the return pipe, but as soon as steam enters the valve the encased composition of the stem expands and closes it. This action is intermittent as the condensation collects and is discharged. A common arrangement of the vacuum pump and receiving tank is shown in Fig. 85.

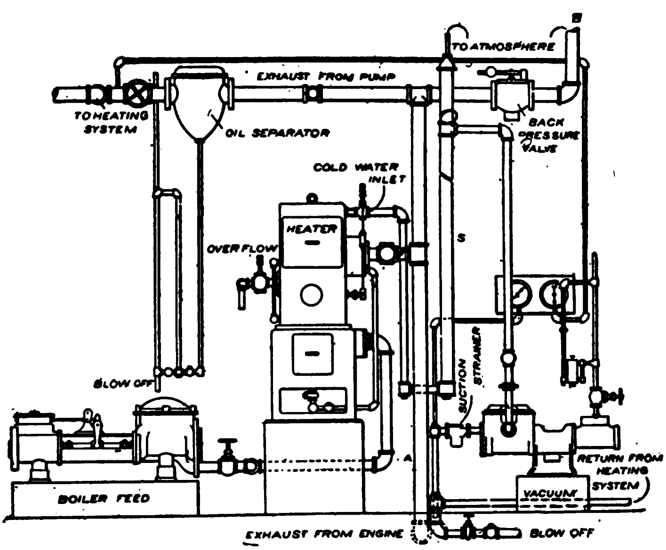


FIG. 86

The boiler-room apparatus and pipe connections of a special system of this kind are shown in some detail in Fig. 86. The exhaust from the engine passes up through the floor, has a single connection with the heater, and then branches; one pipe leading to the heating system through an oil separator, and the other outward through a back-pressure valve. The main return from the heating system enters the vacuum pump at the right through a strainer, which discharges the mixture into a vertical separating chamber, and allows the air to pass out through the vent at the top, while the water passes into an open feed-water heater and receiver of the form shown in Fig. 62.

From here the return is pumped into the boilers by means of the feed pump shown at the left.

A feature of most vacuum systems is the possibility of using graduated valves on the supply ends of the radiators, and thus admitting more or less steam as may be required to produce the desired amount of heat. This is possible as long as the pressure in the returns is lower than that in the radiators, thus permitting the condensation to be sucked out and returned to the boilers.

Vapor Systems. Vapor heating is distinguished from vacuum heating, in that the steam pressure carried in the supply piping is slightly above that of the atmosphere, whereas in the latter system it is below atmospheric pressure. Low-pressure steam, vapor, and a vacuum are merely relative terms when applied to heating, the first applying to pressures of 1 to 5 pounds; the second to pressures of 1 to 5 ounces, and the last to any pressure below atmospheric.

The system illustrated in Figs. 87, 88, 89 and 90 commonly operates under a pressure of 1 to 2 ounces. Temperature regulation is secured by means of a fractional or graduated valve on the supply end of the radiator, by means of which the amount of vapor admitted

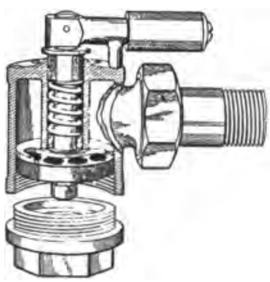


FIG. 87

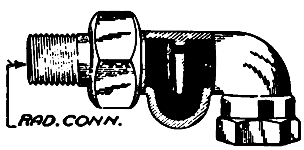


FIG. 88

can be regulated to suit the requirements. A sectional view of this valve is shown in Fig. 87. At the return end of the radiator is a water seal (see Fig. 88), which balances any slight difference in pressure between the radiator and the return main when the supply valve is partially closed. One of the important features in this system of heating is the method of automatically maintaining the low-steam pressure under which it operates. Figs. 89 and 90 are sectional views through a "receiver," which is placed at the side of the boiler. The main return from the radiators enters at the top of receiver through a water seal (see Fig. 89) and passes into the

boiler through the return outlet at the bottom, the connecting pipe entering below the water line.

The air passes from the radiators with the condensation and is carried off through a special pipe connecting with the top of the receiver just above the water seal. This pipe first enters a condensing coil for removing any vapor which may be present, and is then usually connected with a chimney flue. The condensation which forms in the coil returns to the receiver by gravity.

The action of the automatic-pressure regulator is easily explained

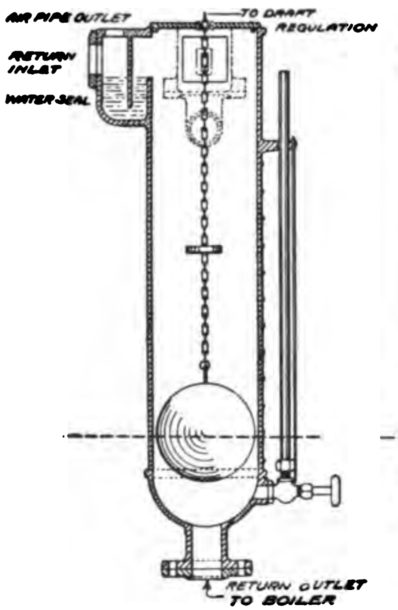


FIG. 89

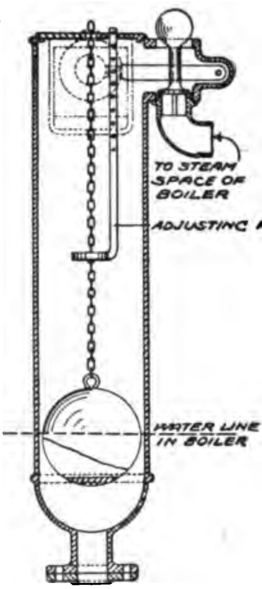


FIG. 90

by reference to Figs. 89 and 90. The receiver is open to the atmosphere and there is a free passage for the water to flow between the receiver and boiler in either direction through the return outlet at the bottom as indicated in the cut.

The slight steam pressure in the radiators and piping is maintained by the water seal at the top of the receiver. When the fire becomes too hot and the steam pressure rises above the point for which the regulator is set, water from the boiler backs into the receiver, the latter being at all times under atmospheric pressure. Any

rise of the water level in the receiver lifts the copper float, and by means of connecting chains closes the drafts to the furnace.

A drop in pressure below the normal has the opposite effect and opens the drafts. A safety device for preventing the water from being forced out of the boiler and overflowing from the top of the receiver, if the ash-pit doors should happen to be left open, is shown in Fig. 90.

Should the float rise to a sufficient height to lift the "adjusting rod" the relief valve will be opened and steam admitted to the top of the receiver, thus relieving the excess of pressure in the boiler and allowing the water to flow back from the receiver through the return outlet.

The system shown in Fig. 91 operates under a low-steam pressure with the returns open to the atmosphere.

Referring to the cut, "A" is a graduated valve for regulating the supply of steam admitted to the radiator; "B," a water seal or

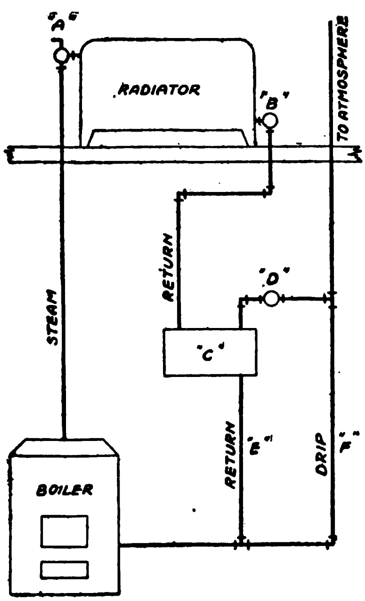


Fig. 91

thermostatic valve for allowing the passage of air and condensation from the radiator into the return without waste of steam; "C" is a tank for the separation of the air from the return water, and "D" a

vacuum air valve which discharges the air from the tank "C" into the atmosphere when there is a slight steam pressure, and which closes when the boiler pressure is less than atmospheric pressure, thus making it possible to operate the system under a low vacuum when desired. The difference in pressure between the boiler and tank "C" is balanced by the water column in return pipe "E," the tank being placed at an elevation above the boiler for this purpose.

Likewise, differences between boiler and atmospheric pressures are balanced by the water column in drip-pipe "F."

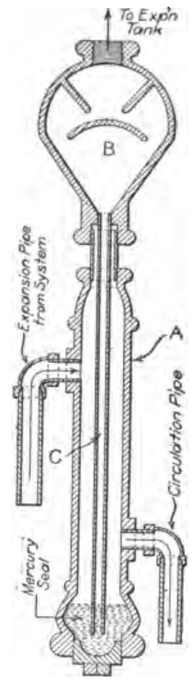


FIG. 92

FIG. 93

The features of this system are the absence of air valves on the radiators, and temperature regulation by means of the graduated supply valve.

There are a number of vacuum and vapor systems in use, but those above described will serve to show the general principles upon which they operate.

Hot-Water Devices. The temperature to which the water can

be raised without boiling in a hot-water heating system depends upon the pressure to which it is subjected.

This, in the ordinary "open system," is 212°, the temperature at which water boils in the open air. In order to raise the temperature of the water and strengthen the circulation through the pipes and radiators, "circulators" or "generators" are sometimes used. A section through a device of this kind is shown in Fig. 92. It is connected into the expansion pipe just below the tank, as in Fig. 93, or at any other point as most convenient.

It consists of a cast-iron cylinder "A," with a chamber "B" at the top, connected with "A" by means of a tube "C." The lower end of "C" is closed by a mercury seal about 1½ inches in depth, as shown.

The expansion pipe from the system enters the side of the cylinder at the left, and the tank connection is taken from the top of chamber "B." The circulation pipe at the right is for producing a flow of warm water through the cylinder, and is only necessary when the device is placed in an attic where there is danger of freezing. When in operation the entire space above the mercury to the expansion tank is filled with water. As the water in the heating system rises in temperature it expands, thus forcing down the surface of the mercury in the cylinder "A" and raising it in the tube "C." This continues until a sufficient quantity has been forced out of "A" to uncover the end of "C." This allows the water to pass upward through the mercury into "B" and thence to the expansion tank. In the meantime a sufficient pressure must be maintained on the surface of the seal to hold it on a level slightly below the bottom of the tube, in order to provide an outlet for the water as it increases in volume.

This pressure depends upon the height of the tube in which the column of mercury is maintained. Ordinarily a pressure of about 10 pounds is carried in the generator.

Automatic Temperature Regulation. There are a number of devices in common use for regulating the amount of heat furnished by systems of different kinds, including steam, hot water, and hot air.

Steam Regulators. The simplest form is the ordinary damper regulator, which simply maintains a steam pressure on the boiler within certain limits. This, however, is hardly a temperature regulator for the building unless it be used in connection with one of the vacuum systems, where it can be set to hold the steam pressure at various points over a considerable range.

Hot-Water Regulators. In the case of hot-water heating, *thermostats* are used for maintaining the temperature of the water at any given point for which they are set. In this way the apparatus may be adjusted to meet the requirements at different seasons of the year, and changes may be made from day to day if desired.

The thermostats commonly used for this purpose consist of a brass tube about 15 inches in length, containing a steel rod attached rigidly at one end. The difference in expansion of these two metals is made to operate a small valve, which in turn admits and exhausts city-water pressure to and from a chamber containing a flexible rubber diaphragm, which is arranged to open and close the dampers of the boiler or heater.

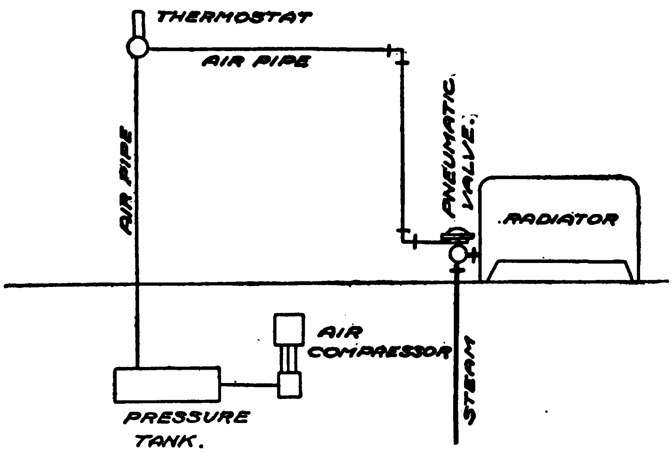


FIG. 94

Motor Regulators. Regulators of this class consist of a thermostat, a motor, and a system of chains and pulleys for connecting the motor with the draft doors. The thermostat in this case is made to operate by changes of temperature in the surrounding air, and is commonly located in some important room where an even temperature is required. The motor is sometimes operated by electric batteries, and sometimes by springs which are wound up at regular periods like those of a clock.

Changes in the temperature of the room cause a sufficient movement of the thermostat to set the motor in motion, and this opens or closes the drafts as required. This type of regulator is usually applied to hot water and hot-air systems.

Pneumatic Regulators. The regulators above described affect only the heat supply to the entire building; that is, the steam pressure is changed, the temperature of the water varied, or the drafts of a furnace regulated. In many buildings it is necessary to regulate the amount of heat supplied to the different rooms independently, in order to maintain an even temperature throughout the building. This is evident because some rooms are more exposed to the sun during different parts of the day, while others are affected by winds or other conditions, so that changes in the heat supply to one room are not necessarily those required by another.

Heat regulation of individual rooms is usually accomplished by the pneumatic system, the principal parts of which are shown in diagram in Fig. 94. In the case of steam and hot-water systems these consist of an air compressor, storage or pressure tank, thermostat, and pneu-

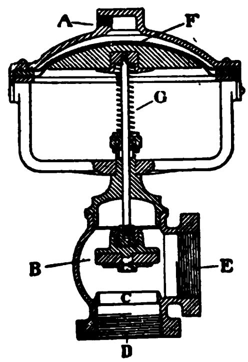


FIG. 95

matic valve. The compressor in small and medium-sized buildings is usually of the direct-acting piston pattern, driven by city-water pressure, while in larger installations steam or electrically driven compressors are employed. The storage tank is of galvanized steel with riveted joints, and is provided with an automatic regulator for holding the pressure at a constant point, so that the compressor is only in use as needed, when air flows from the tank to the valves.

The thermostat operates on slight changes in the temperature of the air surrounding it, and can be set to maintain any room temperature desired.

When the air becomes too warm the movement caused by the

expansion of a metal strip, or the vaporizing of a volatile liquid, opens a small valve and admits air from the pressure tank through the thermostat into the pneumatic valve, thus closing it and shutting off the steam or water supply.

When the room cools below the normal a movement of the thermostat in the opposite direction closes a valve in the air pipe from the tank and allows the pressure in the pneumatic valve to exhaust into the atmosphere, thus causing the valve to open and admit steam or water to the radiator again. A section through a pneumatic valve is shown in Fig. 95. "D" is the inlet from the steam riser, "E" the radiator connection, and "B" the valve for closing the opening "C." Air pressure from the thermostat is admitted at "A" into the space above the flexible diaphragm "F." When the pressure above the diaphragm is exhausted the valve is raised by the coil spring "G" around its stem.

This system of regulation is adapted to both steam and hot water, and may be applied to the registers and mixing dampers of hot-water systems.

TEST QUESTIONS:

(1) What are the advantages of a vacuum system?

(2) Describe two different types of vacuum systems; one for dwelling houses, and one for exhaust-steam heating.

(3) What is a vapor system?

(4) What are the average pressures carried in low-pressure steam, vapor, and vacuum systems.

(5) Describe the action of a circulator or generator as used to increase the circulation in hot-water heating.

(6) How is the temperature of the water in a hot-water heating system regulated?

(7) Describe the action of a motor regulator.

(8) Show by means of a diagram the action of the pneumatic system of temperature regulation.

CHAPTER X

Hot-Blast Heating

The term hot-blast heating, as commonly understood, includes all systems where a fan and heater are used in combination for supplying warm air to a building.

Strictly speaking, this should apply only to cases where the air is delivered at a temperature sufficiently high to heat the building without the use of direct surface in the rooms.

Hot-blast systems are used for warming shops and factories, churches and halls, theaters, schoolhouses, hospitals, etc.

When a single room is to be warmed, as in the case of a church auditorium or hall, the total air supply is heated to a uniform temperature by a single coil or heater placed near the fan, the temperature of the entering air being varied as required by shutting off a portion of the heater or by passing part of the air around it.

When several rooms are to be heated means must be provided for regulating the temperature of the air supply to each independently. This is commonly done in one of two ways—either by the use of supplementary heaters at the bases of the individual flues, or by means of the double-duct system, so called. In the first arrangement the air is heated to a temperature of about 70° by the main heater, and then as much higher by the supplementary as may be necessary to properly warm the room. Temperature regulation is usually obtained by means of a mixing damper at the supplementary, as illustrated in Fig. 43. In the double-duct system two heaters are provided at the fan, one of sufficient size to raise the temperature of the entire air volume to 68° or 70°, and a second heater arranged to take from ⅓ to ⅔ of the tempered air and raise it to a comparatively high temperature. Two ducts are run from the main heating chambers to the bases of the uptake flues, one carrying tempered air, and the other hot air. A mixing damper is provided at the base of each flue for proportioning the mixture of air to give the required temperature to the room.

Ventilation. The amount of fresh air required to produce the necessary degree of purity depends upon the use of the room, the cubic

space per occupant, and the length of time it is continuously occupied. In schoolhouse work the supply per occupant should not be less than 30 cubic feet per minute, and 50 cubic feet is better for high schools. In the case of churches and auditoriums, where the people are assembled for only one or two hours at a time, and where the rooms are usually of considerable height, a smaller supply will suffice, it being customary to provide from 20 to 25 cubic feet per minute per occupant in cases of this kind.

Air for ventilation may be supplied to small buildings by the gravity system, as described in Chapter VI, but the fan system is much more reliable and should always be used in buildings of large and medium size, if possible.

The two systems of hot-blast heating, above described, may be so designed as to give an abundant supply of fresh air, and are widely used in the case of schoolhouses and similar buildings. Another arrangement which gives good satisfaction is to provide a main heater of sufficient size to warm the total air supply to 70° in the coldest weather, and use direct radiation in the rooms for warming, thus making the heating and ventilating systems entirely independent.

This provides a way for warming the rooms without operating the fan when ventilation is not required, and if circulation coils are used the heat is distributed around the outer walls of the room beneath the windows, where most needed. This arrangement is quite extensively used in schoolhouse work.

Exhaust Ventilation. The general term *ventilation* is applied to all cases where air is supplied to or removed from a building, while *exhaust* ventilation refers only to the latter condition of air movement.

In buildings like schoolhouses and churches, where generous flues are easily provided for the exit of the foul air, it is usually sufficient to furnish a supply fan only, the air being forced out by the slight pressure thus produced. In theaters, banking rooms, etc., where free exits are not so easily produced for all parts of the room, it is more usual to instal vent or exhaust fans also. Certain rooms, like toilets, laboratories, and smoking-rooms, where there are likely to be odors, it is customary to provide exhaust ventilation only, and allow the fresh air to be drawn in it through grilles near the floor, or to shorten the doors at the bottom sufficiently to form an air way.

Centrifugal Fans. The fans used for supplying fresh air to a

building are usually of the *centrifugal* type, so called, because the air is drawn in at the center and thrown outward from the tips of the blades by the action of centrifugal force. Such a fan wheel is shown in Fig. 96, and consists of a shaft with steel-plate blades or floats radiating from it. The air is drawn in through the circular openings at the sides and delivered from the tips or outer edges of the blades, which are slightly curved, as shown.

Fans of this type are usually enclosed in steel-plate casings, as shown in Fig. 97, and the air delivered to the distributing ducts through a single outlet, as indicated by the arrows.

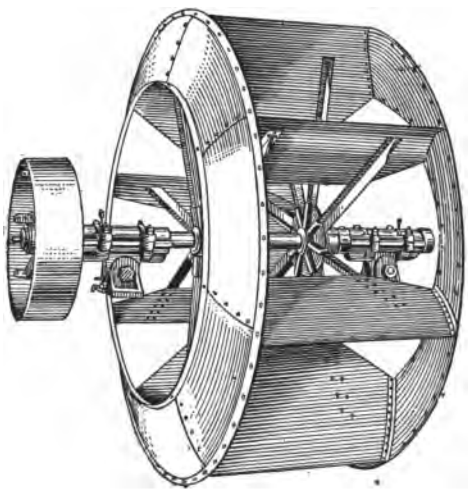


FIG. 96

Multivane Fans. Another type of the centrifugal fan, known as the *multivane,* is shown in Fig. 98. This has a large number of narrow blades or vanes, spoon-shaped, so as to discharge the air evenly the entire length. These fans are smaller and lighter for a given capacity and run at a higher speed.

A fan of this type with its casing is shown in Fig. 99.

Fan Casings. The casings of centrifugal fans are of steel plate, with riveted or bolted joints, and are stiffened by means of angle-iron frames. The style of casing is usually designated by the position of the discharge opening, as top horizontal (Fig. 97), bottom horizontal (Fig. 99), up discharge, down discharge, etc.

When the head room is limited a form called the *three-quarter housing* is commonly used. In this design the casing extends only a short distance below the shaft, the lower part of the wheel running in a sunken pit of masonry or steel construction.

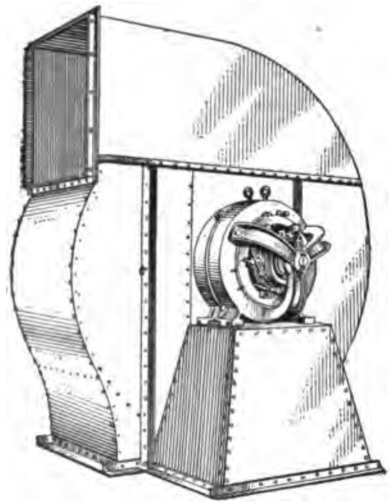


FIG. 97

Propeller or Disk Fans. Although the steel-plate centrifugal fan is frequently used for exhaust ventilation, where there is considerable resistance to air flow, it is more common to use a propeller or disk fan of the general form shown in Fig. 100. In this case the

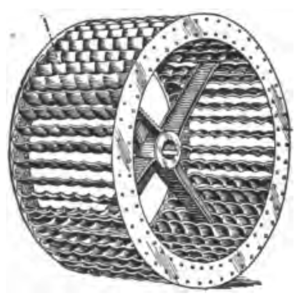


FIG. 98

air is moved in a direction parallel to the shaft, as indicated by the arrows.

This type of fan is lighter and less expensive than the enclosed or

centrifugal fan, and will easily move large volumes of air against small resistances.

These fans are used without a casing, being placed in a wall open-

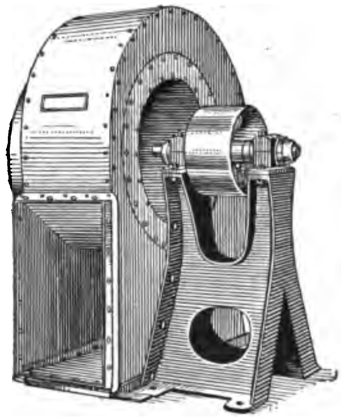


Fig. 99

ing or attached to a partition in a vent duct. They operate equally well either in a vertical or horizontal position.

Engines and Motors. Fans are commonly driven by a steam engine or turbine, or by an electric motor.

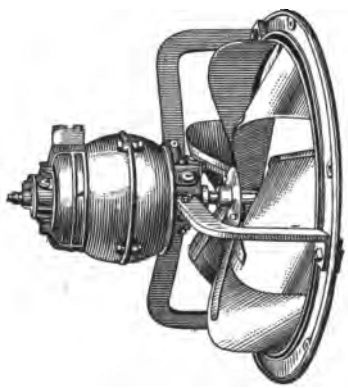


Fig. 100

When placed in the basement of a building, where a solid foundation is easily secured and where steam connections are readily made, an engine or turbine is commonly used, and the exhaust steam turned

into certain sections of the main heating coil reserved for this purpose. In the case of large fans it is customary to furnish the engine with steam at somewhat higher pressure than is used in the heater, on account of the excessive size of engine, if low-pressure steam is used.

With small and medium-sized fans an engine with a cylinder of an especially large diameter is used, so that the necessary power may be developed with a steam pressure of 15 to 20 pounds. In cases of this kind the heater is supplied with steam at the same pressure, and if the heater can be placed at a sufficient height above the boiler, the condensation is returned by gravity. The engine may be connected directly to the fan shaft, or belted as indicated in Fig. 99. When there is sufficient space the belted arrangement is best, as the noise caused by any slight looseness or pounding in the engine is likely to be communicated to the rooms above through the air ways.

Electric motors are well adapted to the driving of fans, especially those of the direct-current type, so that the speed may be regulated to meet the requirements.

Electric motors are best direct connected to the fan shaft, as shown in Figs. 97 and 100, this arrangement being more compact and doing away with any rattling or flapping of belts. Special low-speed motors should be used for fan work. Exhaust fans placed in attics and other places not easily accessible are always driven by motors.

Alternating-current motors are not so well adapted to fan work on account of their high speed and the necessity of belted connections.

Speed Regulation. It is hardly ever possible to estimate the resistance to the air flow with sufficient accuracy to determine beforehand the exact speed at which the fan must be run to deliver the desired volume of air. For this reason it is customary to estimate the probable speed from the results obtained under similar conditions, and then increase or diminish this, as may be necessary, to secure the desired results.

If the fan is driven by an engine, this is easily done by adjusting the governor.

In case of an electric motor it is necessary to connect a regulating rheostat into the circuit. A certain amount of regulation may also be obtained by placing an adjustable damper in the main air duct some distance away from the fan. When this is done the construction should be made very rigid to avoid vibration.

Capacity and Horsepower of Centrifugal Fans. The volume of air moved by a fan depends upon its size and speed, and the resistance against which the air is forced. The size of a centrifugal fan is commonly expressed by the diameter of the wheel in feet, or in some cases by the height of the housing in inches.

Although the relation between the diameter and width of the fan wheel varies somewhat in different makes, the width is made approximately one-half the diameter in the case of standard ventilating fans, and this proportion may be assumed unless otherwise stated.

As the volume of air delivered by a given fan varies so much, according to the frictional resistance of the ducts, it is customary to base the capacity upon the actual results obtained in similar buildings. Table XVI has been computed for steel-plate centrifugal fans (Figs. 96 and 97), in which the widths are one-half the diameters, and the resistance operated against, that which is commonly found in the average schoolhouse, church, or hall. The speeds given in the table are about the average employed for this class of work, and may be varied a reasonable amount in either direction, to give the required air volume.

TABLE XVI

FOR SCHOOLHOUSES, CHURCHES, HALLS, ETC.

Diameter of fan in feet	Revolutions per minute	Cubic feet of air discharged per minute	Horsepower of engine or motor for driving the fan
3	325	4,500	1.5
3½	300	6,600	2
4	275	8,900	3
4½	250	11,300	4
5	225	13,900	5
5½	200	16,300	6
6	175	18,300	7
7	150	24,600	8
8	125	30,300	10
9	125	42,900	14
10	100	46,800	14

EXAMPLES:

(1) A school building has 10 class-rooms, each containing 50 pupils. It is desired to furnish an air supply of 40 cubic feet per minute to each pupil. What should be the size of fan, and the horse power of the engine for driving it?

SOLUTION.—Total volume of air to be supplied per minute is $10 \times 50 \times 40 = 20{,}000$ cubic feet.

Looking in Table XVI it is found that this quantity comes between the capacity of a 6-foot fan and a 7-foot fan. It would probably be better to use the larger size and run it at a slightly lower speed. This calls for an 8-horsepower engine.

(2) A church is to be ventilated by means of a centrifugal fan. The auditorium seats 400 people, and it is desired to supply 20 cubic feet of air per minute to each. What will be the size of fan and motor?

SOLUTION.—Total volume of air to be supplied is $300 \times 20 = 6{,}000$ cubic feet per minute. From Table XVI it is found that a 3½-foot fan, and a 2-horsepower motor are required.

In the case of factories and shops, it is customary to use smaller ducts and higher velocities of air flow. This increases the resistance and makes it necessary to run the fan at a higher speed.

Table XVII has been prepared for work of this kind.

TABLE XVII

FOR SHOPS AND FACTORIES

Diameter of fan in feet	Revolutions per minute	Cubic feet of air discharged per minute	Horsepower of engine or motor for driving the fan
3	400	4,500	1.6
3½	375	6,500	2.5
4	350	8,600	3.5
4½	325	11,200	5.0
5	300	14,000	6.5
5½	275	16,800	8
6	250	19,600	9
7	225	27,000	13
8	200	36,500	18
9	175	45,200	22
10	150	52,800	24

This table may be used for shops and factories in a similar manner to that already described for schools and churches in connection with Table XVI.

Capacity and Horsepower of Propeller Fans. The capacities of disk fans at average speeds, and the power required for operating them, are given in Table XVIII.

TABLE XVIII

FOR EXHAUST VENTILATION

Diameter of fan in inches	Revolutions per minute	Cubic feet of air moved per minute	Horsepower of motor to drive fan
18	800	1,400	.25
24	600	2,600	.4
30	500	4,300	.7
36	400	6,000	1.0
42	350	8,000	1.3
48	300	10,500	1.7
54	250	12,500	2.0
60	225	15,300	2.5
72	200	23,800	3.8
84	175	32,700	5.2
96	150	42,000	6.7

The above table applies to the average conditions of exhaust ventilation with the fan connected to a system of ducts of ample size. When placed in a wall opening, and discharging into free air, without the use of ducts and flues, the volumes of air moved will be considerably in excess of those given in the table.

Main or Primary Heaters. The heaters or coils used in connection with a fan are called *main* or *primary* heaters. These are constructed both of wrought-iron pipe and of cast-iron sections, and are commonly enclosed in a steel-plate casing. When of large size, it is customary to place them in an opening formed by the brick walls of the building, instead of providing an iron casing. A section through a common form of pipe heater is shown in Fig. 101. The pipes in this case are in the form of a loop, with the ends screwed

into a cast-iron chamber which is separated into two parts. The path of the steam through the coils or loops is shown by the arrows. The supply enters the right-hand end of the header or base, then passes upward through the pipes, across the top, and down on the other side of the loop. Both ends of the header are drained into the return, although the greater part of the condensation falls into the return end at the left of the cut, being carried over by the flow of steam.

Another form of heater made up of two banks of cast-iron sections

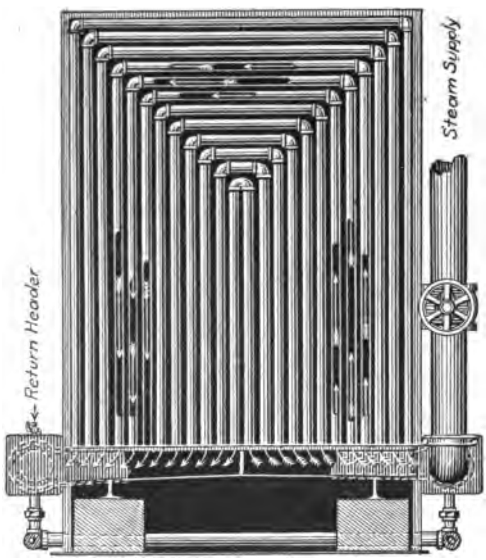


FIG. 101

enclosed in a steel casing is shown in Fig. 102. Indirect radiator sections of the general form shown in Fig. 14 are often used for this purpose by supporting them on iron beams within a heating chamber of brick or concrete.

Size of Heaters. In the case of ventilating work, where the air supply is raised to a temperature of 70° at the fan, and the additional heat for warming the rooms is furnished by secondary heaters at the bases of the flues, or by direct radiation in the rooms, it is customary to provide about 50 square feet of heating surface in the main heater for each 1,000 cubic feet of air to be warmed per minute. This

applies where the air is raised from 0 to a temperature of 70°, which is the usual requirement in northern latitudes. Heaters for this purpose constructed of pipe should be made 8 or 10 rows deep to give the required temperature to the air passing through them.

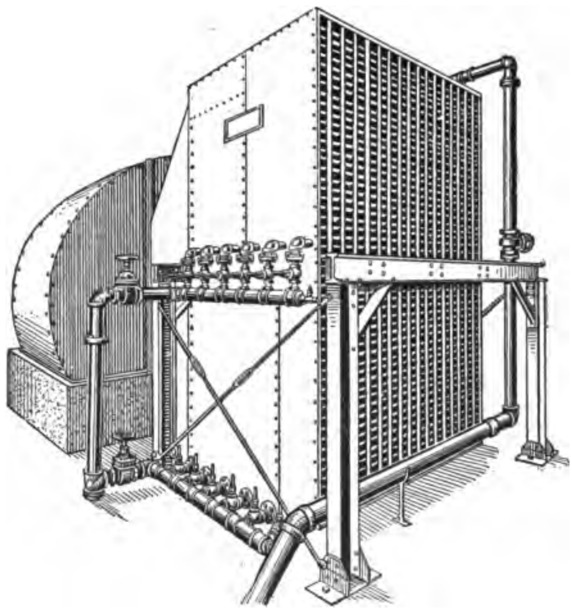


FIG. 102

EXAMPLE:

(3) A school building contains 16 class-rooms, seating 50 pupils each, and 50 cubic feet of air per pupil per minute is to be delivered to the rooms at a temperature of 70° in zero weather. How many square feet of heating surface must the main heater contain?

SOLUTION.—Total volume of air supplied is $16 \times 50 \times 50 =$ 40,000 cubic feet per minute.

Therefore $40 \times 50 = 2{,}000$ square feet of heating surface are required.

When cast-iron sections are used, instead of pipe, the heating surface may be computed in the same manner as above described. The depth of the heater in this case will be sufficient if a single layer of 10-inch sections is used.

Pipe Connections. Primary heaters are usually divided into four to six separately valved sections for regulating the temperature of the air passing through them.

The valves on both the supply and return connections should be easily accessible, and air-valves of large size placed in the return from each section.

When an engine is used for driving the fan, one or more sections should be reserved for condensing the exhaust steam.

The drip from these sections should be trapped into the sewer on account of the oil which it contains.

The following table gives the diameter of supply and return mains for heaters of different size:

TABLE XIX

PIPE SIZES FOR MAIN HEATERS

Diameter of steam main	Diameter of return main	Square feet of heating surface
2″	1¼″	100
2½″	1½″	200
3″	2″	300
3½″	2″	500
4″	2½″	800
5″	2½″	1,200
6″	3″	2,000
7″	3″	3,000

When the distance is short between the boiler and heater, the steam main will supply from 30 per cent. to 40 per cent. more surface than given in the table.

Supplementary or Secondary Heaters. This term is applied to heaters supplied with tempered air which has been passed through a main heater and raised to a temperature of 65° or 70°. These are usually placed in the air ways near the bases of the uptake flues to the rooms.

Heating surface located in this position is more efficient than when placed in the rooms themselves, owing to the higher velocity of the air passing over it. The size of a secondary heater, to be used

under these conditions, may be found by first computing the direct radiation for warming the room and multiplying the result by 0.6.

EXAMPLE:

(4) A room, having a southern exposure, contains 1,500 square feet of wall surface, and 600 square feet of glass surface. What should be the size of a supplementary steam radiator for warming it in zero weather?

SOLUTION.—

$$1{,}500 \div 10 = 150$$
$$600 \div 3 = 200$$

Direct radiation required $= 350$ square feet and $350 \times 0.6 = 210$ square feet, the required size of the supplementary heater.

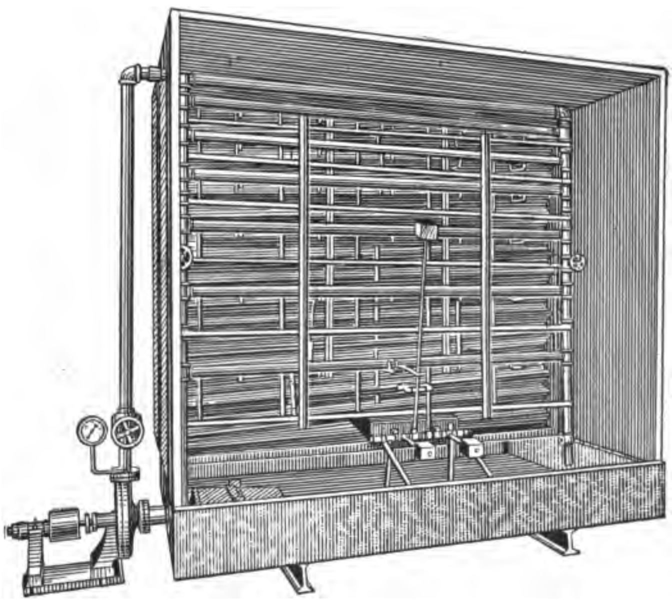


FIG. 103

Air Washers. The extensive use of fans for ventilating purposes in city buildings, makes it necessary to provide some means for removing the dust and soot from the air before it is introduced into the rooms. This is best accomplished by passing it through a spray of

water, as this method removes the impurities without increasing the resistance to any great extent.

A rear view of a typical air washer is shown in Fig. 103. This consists of a chamber of galvanized iron or copper, with a deep pan at the bottom.

A system of pipes, provided with spray nozzles, is carried across the inlet to the chamber, as shown. Beyond this is placed a series of baffle plates. Water is supplied under pressure to the spray nozzles by means of a small centrifugal pump at the left. The entering air first passes through a tempering coil, so called, for raising its temperature above the freezing point in winter weather, then through the spray, which removes the dust and other impurities. After passing the spray the surplus moisture is eliminated from the air by the baffle plates above mentioned, and seen in Fig. 103 beyond the spray pipes. The air is now made to pass through a second heater which raises it to the required temperature before entering the fan for distribution to the various supply ducts and flues.

The spray falls into the pan at the bottom of the chamber and is used over and over again until it becomes too dirty to be effective. It is now discharged into the sewer, and a new supply drawn into the pan from the city mains.

Air washers of this type not only purify the air, but cool it to a certain extent by the evaporation of the spray.

When a decided cooling effect is desired in hot weather, cold water or brine may be circulated through the heating coils.

Ducts and Flues. The ducts and flues for carrying the air to and from the rooms are usually constructed of galvanized iron or brick. When the air ways are underground, either brick or concrete are used for the larger sizes and glazed-drain tile for the smaller branches.

Overhead ducts are nearly always made of galvanized iron.

The uptake flues, both for supply and vent, are commonly of iron, on account of their lightness and the smooth interior surface. In schoolhouses and similar buildings, where the flues are of large size, some architects prefer to construct them of brick. This gives satisfactory results provided the interior is smoothly finished.

The air is commonly brought into the rooms at a height of 7 or 8 feet above the floor, and the tops of the flues should be curved in order to turn the air with as little resistance as possible. The vent openings

should be near the floor and the flues carried upward through the roof as directly as possible. When galvanized iron is used, a hood or cap should be provided at the top, to keep out the rain and snow. As brick flues usually start from the basement floor this is not of so much importance, as any moisture which reaches the bottom will soak into the earth. Supply flues should be provided with adjustable dampers for regulating the air flow to the different rooms, and vent flues should have shut-off dampers for closing when the rooms are not in use.

When a fan is used, the supply flue to each standard class-room should have an area of about 3½ square feet. The vent flues should be made larger, as the air usually flows through them by gravity, assisted by the slight pressure in the room, due to the action of the supply fan.

These are commonly given an area of about 5 square feet. The main supply duct leading from the fan is usually given 1 square foot sectional area for each 1,000 to 1,200 cubic feet of air to be delivered per minute, and the branches to the flues 1 square foot for each 700 to 800 cubic feet.

Factory Heating. This differs from school-house work in that all, or a part, of the air circulated through the fan and heater is taken from the interior of the building instead of from out of doors, and higher velocities are used in the ducts and flues. In this case the air is simply a medium for carrying the heat from the main heater to different parts of the building, the same as the water in a hot-water heating system. In the case of shops and factories the rooms are usually large compared with the number of occupants, and sufficient fresh air will find its way in by leakage. If conditions are such that this does not prove sufficient, then a portion of the air should be taken from out of doors.

If practically all of the air is returned to the fan from the building, there should be approximately 1 square foot of surface in the main heater for each 300 cubic feet of space warmed.

The volume of air to be circulated under the above conditions should be about 20 cubic feet per minute for each square foot of surface in the main heater.

If the air is to be taken from out of doors, increase the size of main heater 50 per cent. Pipe heaters used in this class of work are usually made from 18 to 20 rows deep.

EXAMPLE:

(5) A machine shop 50′ x 200′, and 12′ in height, is to be warmed by a hot-blast system, in which all of the air supplied to the fan is to be taken from inside the building. What should be the sizes of heater, fan, and engine?

SOLUTION.—$50 \times 200 \times 12 = 120{,}000$ cubic feet of space to be warmed.

$120{,}000 \times 300 = 400$ square feet of heating surface.

$300 \times 20 = 6{,}000$ cubic feet of air to be moved per minute by the fan, which from Table XVII calls for a 3½-foot fan wheel, and a 2½ horse-power engine.

If the air were to be taken from out of doors the heater should contain $400 \times 1.5 = 600$ square feet of heating surface.

TEST QUESTIONS:

(1) Define a hot-blast heating system.

(2) What is the double-duct system?

(3) What volume of air per minute should be supplied to the occupants of school buildings? What volume in churches?

(4) What is exhaust ventilation? To what kinds of rooms is it applied?

(5) What is the general form of construction of a centrifugal steel-plate fan?

(6) What is a propeller or disk fan, and for what purposes is it commonly used?

(7) How is the form of casing for a centrifugal fan usually expressed?

(8) What form of power is generally used for driving ventilating fans?

(9) Why is some method of speed regulation necessary?

(10) What is a main or primary heater? How is its size computed?

(11) How is the size of a supplementary heater determined?

(12) What is the use of an air washer? Describe the action of a common form.

(13) What material is commonly used in the construction of ducts and flues for air distribution?

(14) What should be the size of the supply and vent flues for a standard class-room when a fan is used?

(15) How does factory and shop heating differ from the methods employed in schoolhouse work?

(16) How is the size of main heater for factory heating computed, when all of the air is returned to the fan and heater from the building?

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